COTS E3 Risk Assessment Guide

For DOD E3 Systems Engineers

Final Draft for the DOD E3 IPT by the COTS E3 Working Group

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I. Executive Summary

The use of commercial items (CI) or commercial-off-the-shelf (COTS) [hereafter referred to as COTS] equipment presents a dilemma between imposing military E3 standards and the desire to take advantage of existing commercial systems, and accept the risk of unknown or undesirable electromagnetic interference (EMI) characteristics. Regardless of the pros or cons of using COTS, any procured equipment should meet the operational performance requirements, including electromagnetic compatibility (EMC) requirements, for that equipment in the proposed installation.

Integration of COTS electrical/electronic equipment on DOD platforms is an increasingly common practice for a variety of good reasons. COTS typically offer the latest technology and can be cheaper and more quickly fielded than military systems developed from scratch. Unfortunately, commercial equipment is not designed for the harsh electromagnetic environments (EME) found in military platforms and theaters of operation.

One of the biggest difficulties with integrating COTS products into complex military systems is achieving EMC. EMC is the ability of electrical and electronic equipment and systems to share the electromagnetic (EM) spectrum and to perform their desired functions without unacceptable degradation from the EME and without causing EMI to other systems. Blindly using COTS carries the risk of increasing serious EMI problems within the platform or system.

COTS equipment has typically been designed, tested and fielded to much less demanding commercial EMC standards, if tested at all, than MIL-STD 461 or MIL-STD 464. However, the simple fact that it is a commercial item should not be taken as a reason to accept lower EMC performance. Rather than forgoing robust EMC requirements, program managers (PMs), system acquisition personnel and E3 engineering professionals must first assess the EMC-related risk to full operational capability performance from the use of COTS equipment. This document is to be used primarily by E3 engineering professionals. It provides a detailed methodology by which to assess the risk of using COTS and achieving EMC. It does not address when in the acquisition process the assessment should take place, but, rather concentrates on the assessment of risk.

II. Introduction

The use of Commercial Items and Non-Developmental Items (CI/NDI) or Commercial Off-the-Shelf (COTS) equipment allows the military to take advantage of technological advances, cost savings and rapid procurement stemming from the competitive pressures of the commercial marketplace as well as developments in other DOD or government agencies. The use of these items can minimize or eliminate the need for costly, time-consuming, government-sponsored research and development programs.

COTS equipment usage forces the need for a balance between imposing the usual military Electromagnetic Interference (EMI) controls on existing designs, which may have unknown or undesirable EMI characteristics Because these systems are often not designed for the military electromagnetic environments (EMEs), they may malfunction from susceptibility to the EME or cause other operational EMI problems. COTS are typically designed and tested to EMI specifications and standards that don't provide the same protections against undesired emissions and susceptibilities that military EMI standards requirements do. Using COTS carries a risk of fielding equipment with electromagnetic incompatibilities onboard a military platform. To mitigate the risks, a suitability assessment is required to evaluate the installation environment and the equipment's EMI characteristics through a review of equipment design, existing test or analytical data, or even limited testing results.

SD-2, *Buying Commercial and Non-Developmental Items*, An acquisition guidance handbook, defines Commercial Items (CI) and Non-Developmental Items (NDI) as follows:

A commercial item is any product or service that is customarily used by the general public or nongovernmental entities and has:

- Been sold, leased, or licensed to the general public
- Been offered for sale, lease, or license to the general public
- Evolved through advances in technology or performance and is not yet available in the commercial marketplace, but will be in time to satisfy the delivery requirements of a Government solicitation

Non-Developmental Items (NDI), on the other hand, are defined as having been previously developed and used for Government purposes by another DOD /Federal Agency, State or local Government, or by a foreign Government that has a mutual defense cooperation agreement with the US.

Since commercial items/COTS are already designed and built for a commercial EME, the intended operational EME and required E3 performance characteristics must be carefully considered for the desired application during the military acquisition process. Candidate COTS must then be assessed against these criteria for acceptability. EMI problems can present a potentially hazardous situation resulting in unacceptable degradation of mission performance capability, damage to hardware, or even loss of platforms and lives. To mitigate the risk, an assessment should be performed to evaluate the equipment's immunity characteristics against the planned EME and ability to meet the desired performance. Factors to be considered in evaluating the suitability of COTS for military applications include:

- Impact on mission and safety
- The operational EME
- Platform installation characteristics
- Equipment immunity/susceptibility characteristics

After determination of the intended operational environment, the risk assessment process starts with obtaining and reviewing existing design criteria (commercial specs), analysis/test data and conducting additional EMI testing (if necessary.) If the COTS was designed to a commercial standard, or to one from another Government agency, there should exist EMI analysis/test data or a Declaration of Conformity (DoC) (see Appendix A.) That data, if available, should be reviewed to determine if the item is suitable for the particular application or intended installation. If data cannot be obtained, or does not allow comparison with the applicable MIL-STD-461 and/or MIL-STD 464 requirements, laboratory EMI testing should be performed to provide the data necessary to complete a satisfactory comparison. If, after evaluation of the EMI data, it is determined that the equipment would not operate satisfactorily in the intended EME, then the equipment needs to be modified, or it might prove to be necessary to select different COTS equipment with adequate characteristics.

While there are a wide variety of commercial E3 standards available, no single commercial standard covers the EM environments and requirements of the military. There are E3 related standards developed by professional societies such as American National Standards Institute (ANSI), Institute of Electrical and Electronics Engineers (IEEE), Society of Automotive Engineers (SAE), etc. In the United States, the Federal Communications Commission (FCC) regulates emissions (but not susceptibility) of commercial products, commonly referred to as Part 15 and Part 18 devices. Radio Technical Commission for Aeronautics (RTCA) DO-160F, *Environmental Conditions and Test Procedures for Airborne Equipment,* is the closest commercial standard to any US military requirements. It is similar to MIL-STD-461 and should be considered as a valuable resource

On the whole, most COTS equipment has less strict EM requirements (lower immunity levels, higher allowable unintentional emissions, lax or nonexistent susceptibility limits) than military equipment and could therefore be more apt to be upset or damaged when exposed to high level radio frequency (RF) fields or could interfere with legacy systems. Therefore the use of COTS introduces additional risk of incompatibility and can result in problems, plus associated extra costs, in maintaining performance through life and for re-use in other scenarios. When considering COTS or NDI in an acquisition, it is important to include E3 requirements and obtain and review any existing EMI test and/or analytical data.

Figure 1 is a roadmap to systematically evaluate the EMC risk of using a COTS product for a military application.

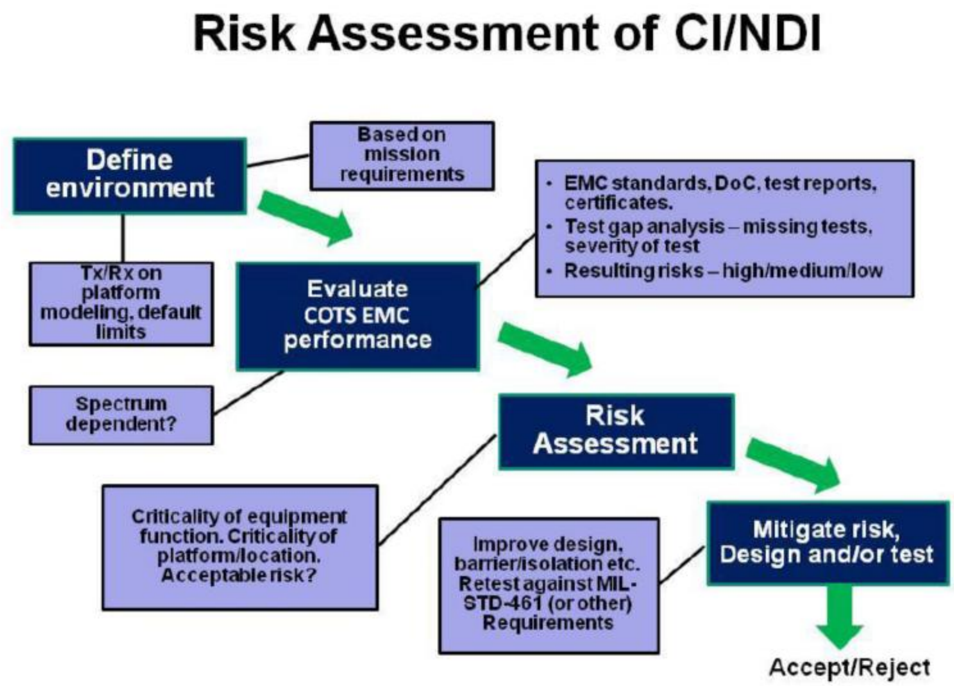


Figure 1 - COTS E3 Risk Assessment Process

[1] Developed originally by Pete Dorey, a Senior EMC Consultant at T�V Product Service Ltd for the UK MoD. Used with permission and adapted for US DOD purposes

The process above requires the intended EME and actual EM performance requirements to be defined, and evidence of commercial EMC compliance to be evaluated. That is followed by a detailed analysis of the "gap" between the actual EMC performance and the required performance. This gap analysis provides the basis for performing a risk assessment of using a particular COTS item for a particular function/mission requirement, in combination with the functional criticality of the equipment and platform as determined by the procuring activity. Finally, the unacceptable risks are to be mitigated by either carrying out remedial re-design, installation methods (EM barriers), or replacement, and/or retesting. Each major block above will be expanded in detail in the following sections.

Define Environment: In order to evaluate the acceptability of the COTS EMC performance, it is necessary to define the EME in which the equipment will operate. For existing platforms the EME may already be defined or may be represented by specifying the requirements documented in standards such as MIL-STD-464. This environment may include geographical aspects regarding the area in which the equipment may be operated, such as operational restrictions of US Part 15 & 18 devices in the United States and radiated susceptibility requirements of European Union /MIL-STD-461.

Evaluate EMC Specification and Compliance Evidence: This process or gap analysis identifies the shortfalls of the existing EMC performance of the COTS equipment. In order to achieve this, the EMC standards, test methods and limits applied to the COTS equipment must be identified and compared to the equivalent EMI tests required (like MIL-STD-461). All available E3 specifications and test data should be obtained when procuring COTS equipment. That will allow a comparison of the commercial EMI test results to the desired military EMI requirements, such as MIL-STD-461.

Once the gaps and missing tests have been identified they can be assigned a risk rating of Low, Medium or High depending on the extent of the deviation from acceptable EM performance requirement. When test reports are not available, the PM may have to conduct E3 testing to determine the acceptability of using the COTS in the acquisition. Risk Ratings will be discussed in more detail later, but the assignment of a quantitative risk is a collaborative effort between the acquiring office and the E3 Engineer. The program office is obviously responsible for defining, assigning and accepting risks on his program. But the nature of the technical expertise necessary to conduct an E3 risk assessment on a COTS item will require that program office relies on E3 engineers for assistance in quantifying and assigning the risks in a meaningful manner to a given procurement.

When the COTS is a piece of spectrum dependent (S-D) equipment, there is also the requirement that it be capable of getting equipment spectrum certification (ESC); this is the PM's responsibility.

Assess Risk against Functional Criticality: The identified gaps must now be compared to the criticality of the COTS equipment (with consideration of the platform criticality as well) to perform its function/mission in the operational EME in which the COTS equipment will be operated. Nil to Low risk will generally be acceptable. In some non-critical situations Low to Medium risk may be acceptable. In all cases a High risk is unacceptable and must be addressed.

Mitigate Risk, Design or Test

There are basically two options if a particular piece of equipment is to be used:

1. Test the COTS equipment to determine compliance with the actual EMC requirements of MIL-STD-461/464 or otherwise. This is technically as good an approach as any; subsequent required protection can be properly specified, and over-protection will be avoided. However, this approach has both cost and schedule implications of the additional testing required.

2. Re-design equipment to achieve acceptable EM performance or provide installation modifications, including adding the appropriate protection 'barriers' to reduce the coupled RF fields , adding gasket material, improving existent bonding between subassemblies, addition of ferrite beads, shielded cables/metal backshells, etc. It is highly recommended to also conduct testing if significant re-design is undertaken to verify that the changes reduce E3 risks. However, this approach has both cost and schedule implications of the additional testing required.

Spectrum supportability (SS) is another issue in the militarization of COTS that must be considered. A chapter in this document is devoted to the management of COTS supportability issues. Modifications which alter the radio characteristics of COTS can create coordination difficulty in trying to obtain ESC and, later, frequency assignments. In many cases, the systems are limited to a non-interference basis and may face severe restrictions.

To summarize, COTS aren't designed with the harsh military operational EME in mind. S-D equipment is designed for use in commercial, not DOD, bands. Commercial EMI control, design and test requirements documents that do exist aren't typically stringent enough for military purposes, from either an emissions or a susceptibility perspective. Thus, using COTS equipment can introduce performance risk that must be managed and can actually cause more harm than good if their characteristics are incorrectly assessed. This document provides guidance on how to assess these risks.

III. Determining the Electromagnetic Environment (EME) and EM Requirements

Defining ALL the EMEs and EMC requirements is the most critical step in conducting a risk assessment/analysis. The deployed operational EME is often the only environments considered; storage, transportation, and repair are examples of environments that are forgotten or not considered. They will be covered later on in this section.

While this document concentrates on EMI requirements, comparisons and gap analyses, understanding the application of EMI requirements can assist with the determination of adequate EM protection in other areas, such as applying E3 transient tests to help determine resistance to lightning damage or EMP.

The simplest EME definition for a COTS E3 Risk Assessment would be to use tables from MIL-STD-464 for the appropriate platform type in which the COTS will operate. But to properly define and tailor an overall EME definition for the COTS application, many other factors should be considered.

Systems will generally be intended for use in a number of operational scenarios with differing EMEs but there are likely to be only a limited number of scenarios that are significantly different. It is convenient to categorize the systems by platform so that its overall EME can be determined. Looking at the primary platform operating environment (i.e., sea, land, air) in relationship to the types of expected EM threats will reveal important similarities and correlations between each of these main types of environment. The result is the table below, from UK Defence Standard 59-411, Part 2.

Considering the EM threats detailed in the table below will go a long way toward a more detailed definition of the overall EME for a COTS application and give the assessor more information by which to tailor both the EME and the desired EMI performance requirements. These two items together, the defined EME and the tailored EMI requirements, will provide the basis against which to conduct the risk assessment by comparing the actual COTS EMI performance.

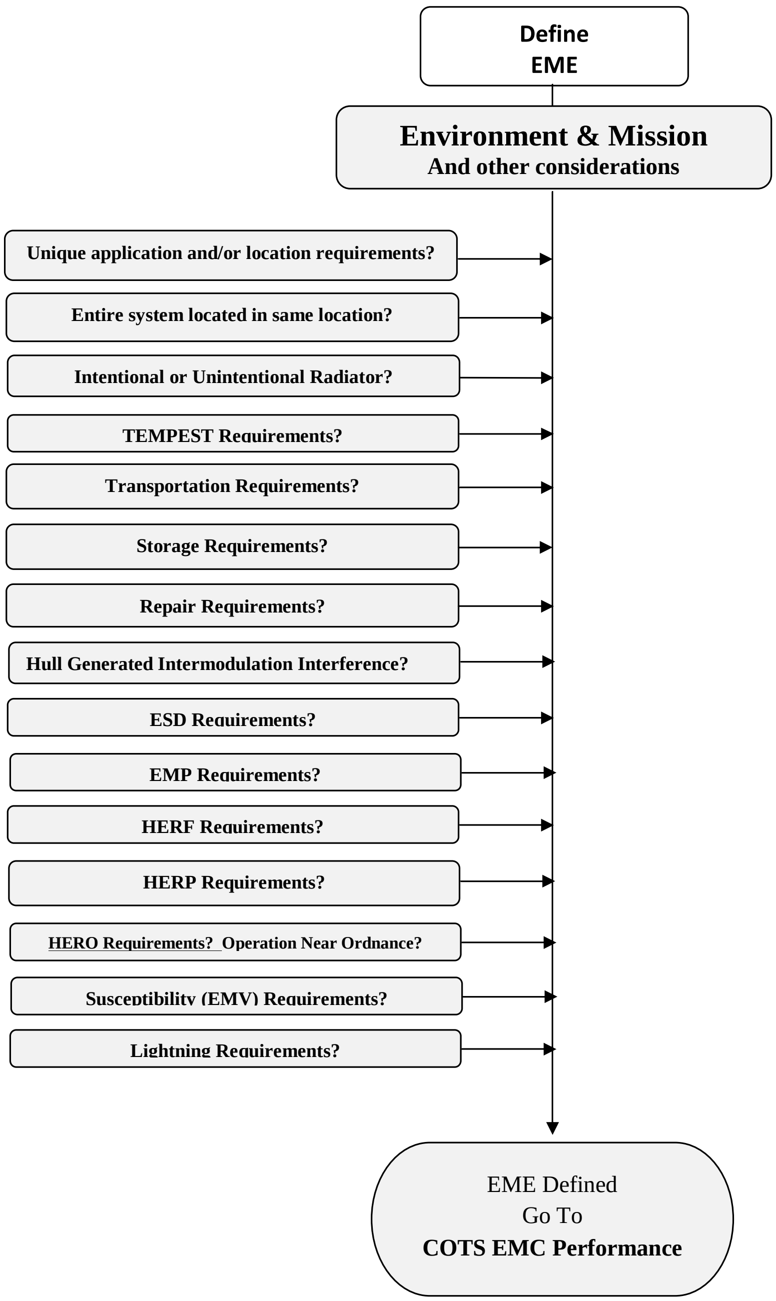
One can then further subdivide the EME descriptions into the different EM threats in each scenario. Table 1 below shows a categorization by platform type for which the EM environments can be significantly different. Although there are different environments for different situations, it may be necessary to look at only the worst case threats when testing a system (for example, one would not produce an aircraft that was compatible with the in flight EME but not compatible with the airbase or shipboard EME). From this chart one can determine some of the EM threats that need to be addressed for each platform and the relationship to the other platform environments. As an example, if the COTS equipment is to be used on a surface ship AND is to be used on a submarine, the EMEs are different and the E3 test requirements are different. Initially both required EMEs need to be included for analysis.

Threat	Air	Sea	Land	Ordnance
Lightning	a) Indirect strike b) Direct strike	a) Ground nearby strike b) Ground Direct/ Indirect strike	a) Ground nearby strike b) Ground Direct/ Indirect strike	a) Ground nearby strike b) Direct/Indirect strike
Electrostatic discharge (ESD)	a) Rotorcraft ESD b) P-Static c) Human ESD d) Discharge from other materials	a) Human ESD b) Discharge from other materials	a) Human ESD b) Discharge from other materials	a) Human ESD b) Discharge from other materials c) Rotorcraft ESD d) P Static
Conducted EM energy	a) In flight, power generated internally b) On ground, as for land service c) On ship flight- deck as for sea service	a) At sea, power generated internally b) In port, as for land service	a) Power generated by field / vehicle generators b) Power from civilian mains distribution c) Telephone, LAN and other data input /output lines	a) Own internal generated power b) External power as relevant land / sea / air platform
Static and Low Frequency Fields	a) Power System Magnetic Field b) Terrestrial Electric Field	a) Power System, Degaussing and Deperming Magnetic Fields b) Terrestrial Electric Field	a) Power System Magnetic Field b) Terrestrial Electric Field	a) As for relevant platform environment
Radiated Communications / Radar	a) Rotary at airfield b) Rotary in flight c) Rotary near / on ship d) Fixed Wing at airfield e) Fixed wing in flight f) Fixed wing near / on ship	(a) Above decks (b) Submarine (c) Rotary Wing near / on ship (d) Fixed Wing near / on ship	a) Different classes based on proximity of transmitting antennas.	a) Full life cycle (derived from one or many platform systems) b) Operational as for land / sea / air as appropriate.
Nuclear Electromagnetic Pulse (NEMP)1	a) Endo- atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo- atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP	a) Endo-atmospheric NEMP b) Exo-atmospheric NEMP
NOTE This standard does not address other effects produced by a nuclear explosion such as Transient Radiation Effects on Electronics (TREE) or Initial Nuclear Radiation (INR). The Equipment Capability Customer should be consulted as to whether hardening to these effects is required. In the relatively few cases where it is called up Def Stan 08-4 should be consulted.				

Table 1 - EM Threats vs. Platforms

The following diagram is provided to pose questions regarding major EM requirements areas that may be asked and answered when considering a piece of COTS equipment for use in a military EME. This can help expand on the details noted from the initial EME assessment based on Table 1. A brief discussion of each question is provided to give more clarity to the question. If these questions are accurately answered, a good description of the required EME has been assembled and a gap analysis can be conducted on the COTS equipment documented EM performance. It should be noted, that this list is only guidance.

Additional environments may need to be added, based on the nature of the product and where it is to be used. For example, the EMP section could be expanded to include other hostile electromagnetic environments (EME), tailored to the expected mission profile of the platform, which may include non-nuclear EMP (e.g. E-bomb), high-powered microwave (HPM), jammers, or other hostile electronic warfare (EW) sources. While beyond the scope of the examples provided in this document, it would be useful to sub-divide the EME into friendly and hostile military environments, which would be of use in determining COTS risks on non-combat platforms (engineering support vehicles, costal patrol ships, transport aircraft) whose mission profile would see them exposed to friendly EME, but would not likely be exposed to hostile EME such as EMP, high-powered microwave (HPM), jammers, or other hostile electronic warfare sources.


Define
EME
Environment & Mission
And other considerations
Unique application and/or location requirements?
Entire system located in same location?
Intentional or Unintentional Radiator?
TEMPEST Requirements?
Transportation Requirements?
Storage Requirements?
Repair Requirements?
Hull Generated Intermodulation Interference?
ESD Requirements?
EMP Requirements?
HERF Requirements?
HERP Requirements?
HERO Requirements? Operation Near Ordnance?
Susceptibility (EMV) Requirements?
Lightning Requirements?
EME Defined
Go To
COTS EMC Performance

Unique application and/or location requirements?

Application and location requirements must be determined to ensure the COTS equipment is effectively evaluated for use in the military application. The application and/or location of the COTS equipment may not be according to the classifications normally expected by the military standards. An example is stated in MIL-STD-464 which asks:

- Above Deck?   An area on ships, which is directly exposed to the external Electromagnetic Environment.

- Below Deck?   An area on ships which is surrounded by a metallic structure or an area which provides equivalent attenuation to electromagnetic radiation

Both are different environments, but the above questions need to be answered. Basically, these questions are aimed at the COTS equipment being used on surface ships and submarines. Answering both questions is important to ensure one or both environment requirements are considered within MIL-STD-464 when applicability is determined. Comments about equipment used on shore stations, aircraft and other platforms will be addressed later.

Entire system located in same location?

A system may consist of several subsystems located within different environments. A good example is a radar. It tyically consists of an antenna, control assembly, and a monitor, and all three are normally not located in the same area and are potentially in different EMEs. Each subsystem EME needs to be defined and evaluated, based on where each will be located. Normally the entire system is looked at as a whole and the most stringent E3 requirement is used for the analysis. A more effective approach in the use of COTS might be to apply different EMEs (from MIL-STD-464, for example) or different MIL-STD-461 requirements to the different pieces of the system to better assess its overall performance. One could even take actual EME measurements in each area with the antenna, control assembly, and monitor in place of using the requirements of MIL-STD-464. In any event, care should be exercised when determining the E3 requirements for a system that consists of several subsystems not colocated in one EME.

Intentional or Unintentional Radiator?

Intentional radiators are devices that generate and emit RF energy by radiation or induction on purpose as part of their operation. Typical Examples:

− Radar Systems

− Portable Communication Devices (PCDs) including cordless telephones, portable radios (“walkie-talkies”), cell phones, and radio-frequency identification (RFID) systems

− Remote Switches, door controls, alarms

− Wireless Local Area Network (WLAN) and wireless laptop computers

Subsystems and equipment that use, transform, or generate undesired EM energy as a by-product of performing its mission are considered to be unintentional emitters. Typical Examples:

− Intentional radiators emitting other than the intended emission

− Computers and associated peripherals

− Televisions, cameras, and video equipment

− Microwave ovens

− Radio and radar receivers

− Power supplies and frequency converters

− Motors and generators

− Electrical hand tools

Stating that the proposed COTS equipment is an intentional or unintentional radiator is a statement used in the national and international commercial community to categorize and determine resultant testing scenarios.

EMSEC/TEMPEST Requirements?

If EMSEC/TEMPEST is a requirement refer to “NSTISSAM TEMPEST/1-92 and CNSS Advisory Memorandum TEMPEST 01-02” which provides testing methodology for verifying compliance with TEMPEST requirements, which would be over and above EMI testing.

Storage , Transportation and Other Non-Operational EME Requirements?

EMEs are different for different phases of an equipment’s lifecycle, particularly for non-operational phases, such as for storage or different modes of transportation. Storage and transportation EMEs can be of major importance, especially if the requirements do not match the requirements of MIL-HDBK-235 and MIL-STD-464. While non-operational EMEs might tend to be more benign than operational EMEs, there may be times when items are stored or being transported near high powered transmitters. MIL-STD-464 can provide additional guidance on these types of requirements.

Hull Generated Intermodulation Interference? (IMI)?

The Navy has a concern with controlling higher order modulation (IMI) products, most specifically aimed at S-D equipment operating in the High Frequency (HF) band, to permit effective use of the spectrum. This is a consideration for shipboard COTS installations and will contribute to the definition of the EME. If this is a requirement for the COTS equipment, refer to MIL-STD-464 and the particular requirements that are supplied.

ESD Requirements?

ESD occurs when the static electric field between two objects exceeds the dielectric strength of the air between them. ESD primarily affects systems at the component level. Examples of sensitive components that can be damaged are:

- Microcircuits

- discrete semiconductors
- thick film resistors
- hybrid devices
- piezo-electric crystals

ESD can cause intermittent or upset (transient) failures as well as hard failures. Intermittent failures occur when the equipment is in operation and is usually characterized by a loss of information or temporary distortion of its functions. Depending on the operational scenarios for the COTS equipment, the ESD environment can be significantly strenuous such as in the case of equipment exposed to vertical lift and in-flight refueling environments. Requirements and guidance are contained in MIL-STD-464 and 1686 and MIL-HDBK-263.

EMP Requirements?

High-altitude EMP (HEMP) is generated by a nuclear burst above the atmosphere which produces coverage over large areas and is relevant to many military systems. This EME is classified and is currently defined in MIL-STD-2169. EMP requirements are normally imposed on equipment and subsystem enclosures when they are located external to a hardened (shielded) platform or facility.

MIL-STD-461, RS105, Radiated Susceptibility, Transient Electromagnetic Field is used to verify the ability of the equipment under test (EUT) enclosure to withstand a transient EM field such as that created by an EMP. The equipment or subsystem enclosure shall not exhibit any malfunction, degradation of performance, or deviation from specified indications. This requirement is applicable only if invoked by the procuring activity. Potential equipment responses due to cable coupling are controlled under CS116.

And as previously mentioned, EMP requirements could be expanded to include other hostile EME sources such as non-nuclear EMP, HPM and other hostile EW sources, particularly for COTS use on combat platforms (as opposed to support platforms).

COTS equipment is not normally designed and tested to EMP requirements, only when required by the military for specific applications. Therefore, EMP conformance can be a major stumbling block in qualifying COTS equipment, imposing substantial design changes and testing requirements.

HERF Requirements?

Hazards of EM radiation to Fuels (and volatile materials) (HERF) is the potential hazard that is created when volatile combustibles, such as fuel, are exposed to EM fields of sufficient energy to cause ignition. HERF considerations will exist if the COTS equipment is a RF transmitter of significant power and is to be located/operated near volatile combustibles.

Requirements to control EMR hazards to fuels are in MIL-STD-464. NAVSEA OP 3565/NAVAIR 16-1-529, VOLUME 2 provides procedures for establishing safe operating distances.

HERP Requirements?

Hazards of EM radiation to Personnel (HERP) is the potential hazard that exists when personnel are exposed to an EM field of sufficient intensity to heat the human body. Radar and EW systems present the greatest potential for personnel hazard and will most likely have HERP requirements.

MIL-STD-464 requires compliance with current policy spelled out in DODI 6055.11, Protecting Personnel from Electromagnetic Fields. It identifies the controls for personnel exposure to Electromagnetic Fields (EMF), EM radiation (EMR) and lists the present maximum permissible exposure (MPE) levels. If the COTS equipment is an intentional EMF radiator system refer to DODI 6055.11 for more information.

Host nation requirements for HERP (RADHAZ) might be required if the system is to be installed overseas. Refer to STANAG 2345 and Ministry of Defence Standard DEFSTAN 59-411 Part 5 for more international requirement information.

HERO Requirements?

Hazards of Electromagnetic Radiation to Ordnance (HERO) is the potential hazard that exists when ordnance, or explosive devices are exposed to RF fields. HERO is the danger of accidental ignition or dudding of electrically initiated devices (EIDs) in ordnance due to RF fields. If COTS equipment is to be operated near ordnance, ordnance safety requirements are mandatory. It is possible that EMF levels can cause premature actuation of ordnance EIDs. RF energy of sufficient magnitude to fire or dud EIDs can be coupled from the external EME, either by explosive subsystem wiring or by capacitive coupling from nearby radiated objects. Possible consequences include both hazards to safety and performance degradation. If the COTS equipment is operated near ordnance, HERO safety analyses must be undertaken to ensure that emissions from the COTS do not exceed the maximum allowable EMR levels for the ordnance items.

Transportation, shipping and other non-operational EMEs were mentioned previously, but HERO represents a special case for which you need to understand the operational EME for all of the Stockpile-to-safe separation sequences (S4). Thus, for HERO, the characterization of the operational EME where ordnance is transported/stored, assembled/disassembled, staged, handled/loaded, platform loaded, as well as the immediate post-launch environment (vicinity of ship) would be required. And requirements will differ depending on the procuring service.

A good example of the problem is that, during shipment, storage, checkout and launch, a missile will be exposed to different EME levels. While a missile would not likely be a COTS item, it may incorporate COTS components in its design. Overall, the missile's performance must not be degraded by any specified EME. EMI Performance requirements should ensure the COTS performance is not adversely affected by any of the EME levels that will be encountered.

Refer to MIL-STD-464 and MIL-HDBK-240 for HERO requirements and evaluation guidance.

Additional guidance:

NAVSEA OP 3565/NAVAIR 16-1-529, VOLUME 2	Electromagnetic Radiation Hazards (Hazards to Ordnance)
AECTP-508/3	NATO HERO Guidance
OD 30393	Design Principles and Practices for Controlling the Hazards of Electromagnetic Radiation to Ordnance (HERO Design Guide)

MIL-STD-1576 Electro-explosive Subsystem Safety Requirements & Test Methods for Space Systems

EM Vulnerability (EMV) (Susceptibility) Requirements?

EMV is the characteristic of an item that causes it to suffer degraded performance, or the inability to perform its specified task, as a result of the operational EME. An item is said to be vulnerable if its performance is degraded below a satisfactory level because of exposure to the stress of an operational EME or transient. There are many different EME levels that a COTS item will be exposed to during its life cycle. Many threats will be seen only infrequently. However, if the COTS encounters an operational EME corresponding to its susceptibility characteristics as observed in a laboratory test, it may suffer degradation in performance, or not be able to perform its specified task at all in that operational environment.

Lightning Requirements?

Lightning can affect a system in two distinct ways, directly or indirectly.

Direct effects are any physical damage to the system structure or equipment due to the direct attachment of the lightning channel. These effects include tearing, bending, burning, vaporization, or blasting of hardware, as well as the high-pressure shock waves and magnetic forces produced by the associated high currents.

Indirect effects are those resulting from electrical transients induced in electrical circuits due to coupling of the EM fields associated with lightning and the interaction of these fields with equipment in the system.

The fact that MIL-STD-461 is really a set of EMI requirements intended to serve a wide range of platforms, from ships to aircraft to submarines to fixed installations, special applications such as “above and below deck” reflects that there are some tests that need to be covered by another means. Lightning is one of them.

Operational performance requirements related to EMC in MIL-STD-464do not directly correlate to a set of tests specified in MIL-STD-461. Conducting CS115 & CS116 as a prerequisite to EMP testing will satisfy some of the requirements of MIL-STD-464 for lightning, however, reference to more applicable military or commercial standards for requirements and guidance in the design of lightning protection systems applicable to a specific platform.

Initially, refer to MIL-STD-464 for your electromagnetic environmental effects (E3) interface requirements and verification criteria for your airborne, sea, space, or ground system and then refer to the military and/or commercial standard(s) that are requested. For instance, DO-160E provides lightning transient test procedures.

Below is a list of lightning standards for your reference. As can be seen from the descriptions, lightning standards have been created based on specific platforms, such as aircraft. It stands to reason that an aircraft standard would not necessarily be the correct standard applicable to testing munitions.

EUROCAE ED-84F Aircraft Lightning Environment and related test waveforms

NFPA 78-89	Lightning protection code
SAE ARP-5416	Aircraft Lightning Test Methods
SAE AIR 1406-76	Lightning protection & ESD
DEFSTAN 02-516	Guide to Lightning Protection in HM Surface Ships
RTCA/DO-160E	Environmental Conditions and Test Procedures for Airborne Equipment, Section 22: Lightning Induced Transient
DEFSTAN 59-411	Electromagnetic Compatibility, Part 2, Electric, Magnetic & Electromagnetic Environment
STANAG 4327	Lightning Munitions Assessment and Test Procedures
AOP 25	Lightning discharges assessment and tests rationale and guidance
AECTP 505	Verification methodology for the electromagnetic hardness of aircraft
NCS 10	Conducted Susceptibility, Imported Lightning Transients (Aircraft / Weapons)
AECTP 508/4	Lightning, Munitions Assessment and Test Procedures

A. Categorization

Developing a methodology to categorize COTS into specific groups can help to define the overall EMI requirements, based on the category function and location (primarily). One method is to categorize equipment by Equipment Type according to Function (in relation to the use of the equipment), which helps determine some primary EMI control requirements. Category tables can be created for major generic platform types, such as those listed in the MIL-STD-461 Applicability Table. The platform type helps determine the overall EME. The combined EME and EMI requirements for each category and platform must be carefully evaluated to ensure both minimal risk of EMI and reduced cost to achieve EMC in the platform environment. This evaluation must include the expected location, exposure, and use of the platform.

At the time of the drafting of this guidance document, there exist few good categorization methodologies for our purposes. The primary reason is that generic categories will require extensive modification for each particular COTS E3 risk assessment application, as often as not. Some thoughts and examples are presented so that the reader may develop their own categorization schema as appropriate.

The best example thus far is shown in Table 2 below, provided for shipboard equipment. It is based originally on a categorization of shipboard equipment given in IEC International Standard 60533, **Electrical and electronic installations in ships – Electromagnetic compatibility** and modified for Navy use in the EM-TARTT EMI requirements tailoring tool (see Appendix H). Each category has associated with it different EME and EMC requirements and equally important, different levels of EM risk acceptability. The idea is that using COTS in certain equipment groups that are less mission-critical or are inherently more protected from the EME (based on location or installation) is less risky that other uses. Subsequently, different EMI requirements are imposed. In the case of the IEC 60533 categories, specific IEC EMI standards apply. In the case of EM-TARTT, different tailored sets of MIL-STD-461 requirements are generated. In any case, the acquisition requirements should reflect that the equipment will operate at full performance and will not present interference to other mission critical equipment.

Shipboard Equipment Categories		
Category	**Equipment and Installation Groups**	**Examples of Applicable Devices**
A	**RADIO COMMUNICATIONS AND NAVIGATION EQUIPMENT**	Receivers, Transmitters, Meteorology, GPS, INS, Gyro System, SATCOM, HF, VHF, UHF, Magnetic Flux Compass, Misc.
B	**POWER GENERATION, PROPULSION, CONVERSION**	Motor Generators, Motors w/sensors, Variable Speed Drive, Voltage regulators, Breakers, Solid State Frequency Changer, Electric Drive System, Misc.
C	**PULSE POWER INTENTIONAL RADARS**	Navigation Radar, Combat Radar, Sonar, I/O Systems, EW Emitter, IFF, TACAN, Beacons, HF, Misc.
D	**MACHINERY CONTROL, SWITCHGEAR**	Ship Control System, Local & Remote Controls, Damage Control, Switch Boards, Electronic Control, Machinery Control, Steering Control, Data Acquisition Units (DAU), PLC, Misc.
E	**IT, C4I, INTERIOR COMMS, DIGITAL**	Computers, Servers, Routers, Wireless Voice/Data, Digital Equipment, UPS, Interior Communications, Electronic Equipment Cabinets
F	**PASSIVE SYSTEMS (NON ELECTRONIC)**	Passive Heaters, Transformers, Induction Motors, Rigging, Misc.
G	**HULL, MECHANICAL & ELECTRICAL**	Medical Equipment, Fork Lifts, Conveyor Lifts, GP Test Equipment, Window Heaters, Cranes, Winches/Electrical, Misc.
H	**WEAPONS, GUNS, MISSILES**	Missiles, Guns, Weapons, Misc.

Table 2 - Shipboard Equipment Category Examples

Another example of categorization is presented in MIL-STD-461C which contained categorization tables for the three services with attendant EMI requirements for each category. MIL-STD-461C provided a series of equipment and subsystem classes (Table 1-II in that document) that directed the user to specific

EMI requirements in different “Parts” of the document. The classes described use on specific platforms (Class A), items support Class A items but not in critical areas (Class B) and Miscellaneous/General Purpose items not associated with a specific platform (Class C). Class C includes a section for commercial electrical and electromechanical equipment (Class C3). The user is directed to Part 10 of MIL-STD-461C which delineates EMI requirements for this class of equipment. Some of these requirements might represent appropriate EMI requirements to apply to COTS applications but an analysis of -461C requirements versus currently acceptable EMI requirements would be required. That is beyond the scope of this document.

The categorization concept would lead to the development of an EMI Requirements Matrix, such as the one shown below in Table 3, which would show the acceptable or desired EMI requirements for each category of equipment. Table 3 lists tailored EMI requirements from IEC 60533, which lists EU type requirements for various equipment categories. Bear in mind that the table below is designed to be applied to a wide variety of equipment groups; in the case of a specific COTS E3 Risk Assessment, the interest would be in a small number of specific group requirements (i.e. specific lines listed in the table).

Group	Equipment- and installation groups	Examples of applicable devices		CISPR 16-2	CISPR 16-2	IEC 61000-4-16	IEC 61000-4-11	IEC 61000-4-11	IEC 61000-4-4	IEC 61000-4-5	IEC 61000-4-6	IEC 61000-4-2	IEC 61000-4-3
				Conducted emission	Radiated emission	Conducted low frequency interference	Power supply variation	Power supply failure	Electrical fast transients	Surge voltage	Conducted radio frequency interference	Electrostatic discharge (ESD)	Electromagnetic field
A	Radio communication and navigation equipment	Maritime radiocommunication and navigation equipment and systems	Transmitters and receivers for maritime radiocommunication and navigation services	x	x	x	x	x	x	x	x	x	x
B	Power generation and conversion equipment	Electric machinery	Induction motors/generators	-	-	-	-	-	-	-	-	-	-
			Synchronous machines	x	x	-	-	-	-	-	-	-	-
			DC-machines	x	x	-	-	-	-	-	-	-	-
			El. machines controlled by electronic equipment	x	x	x	x	x	x	x	x	x	x
			Special electrical machines	x	x	x	x	x	x	x	x	x	x
		Electronic exiters	AVR's: Automatic Voltage Regulators	x	x	x	x	x	x	x	x	x	x
			AVR's - additional equipment	x	x	x	x	x	x	x	x	x	x
		Converters	Cyclo-converters	x	x	x	x	x	x	x	x	x	x
			Synchro-converters (DC-link)	x	x	x	x	x	x	x	x	x	x
			Pulse-width-converters	x	x	x	x	x	x	x	x	x	x
			DC-converters	x	x	x	x	x	x	x	x	x	x
		Transformers		-	-	-	-	-	-	-	-	-	-
C	Equipment operating with pulsed power	Maritime navigation equipment	Radar and sonar systems, echosounders	x	x	x	x	x	x	x	x	x	x
D	Switchgear and control systems	Circuitbreakers/contactors	without electronics	-	-	x	-	-	-	-	-	-	-
		Electronic control devices		x	x	x	x	x	x	x	x	x	x
		Relay operated control devices		-	-	-	-	x	-	x	-	-	-
E	Intercommunication and signal processing equipment	Electronic alarm monitor		x	x	x	x	x	x	x	x	x	x
		Electronic control system		x	x	x	x	x	x	x	x	x	x
		Automation system		x	x	x	x	x	x	x	x	x	x
		Computers, sensors		x	x	x	x	x	x	x	x	x	x
F	Non-electrical items and equipment	Rigging	Generation of parasitic broadband interference	not applicable									
G	Integrated systems	Cargo monitoring system with sensors and equipment in different zones	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x	x
		Integrated Navigation System (INS)	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x	x
		Integrated Bridge System (IBS)	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x	x

Table 3 - Equipment Requirements Matrix

X: test required -: test not required)

It must be noted that while “categorization” may be an acceptable way to assist in the determination of expected EME and general EMI requirements for a COTS item, there are currently no such tables developed for application by specific services or on particular platforms. That task may be undertaken in the future by the COTS E3 Working Group and would require consideration of some of the following ideas:

- Can this structure to other generic military platform types (aircraft, ground vehicle, etc.)?

- Are there EME assumptions for each group? What is the generic EME and what are the acceptable/minimal/tailored EMI requirements for the different platform categories for each service.
- What is the relative criticality level of the various categories (i.e., what groups are more important than others)? How is that scale developed?
- How does the criticality affect the desired EMI requirements (i.e., if one group is of lower importance than another, what EMI requirements are being relaxed or dropped?

Category definitions may also factor in equipment criticality. The less critical the equipment (based on its intended function relative to the platform/system mission), the more E3-related risk is acceptable. Adding criticality obviously tends to complicate categorization but it's a distinction that will be useful later in the risk analysis. During the risk analysis portion of the assessment, the criticality of the system helps determine level of risk "acceptability" (i.e., low, medium, or high risk).

So how is mission criticality to be defined? Sample definitions, used in the EMP world, include:

- Mission-critical equipment (MCE). Deemed by the procuring and/or operational authority to be essential to successful performance of the ship's mission.
- Mission-critical failure. Either functional upset or damage which results in unacceptable performance degradation as determined by the operational or procuring authority.
- Mission-critical subsystems. MCS consists of all MCE and support equipment required to perform critical trans- and post-HEMP attack missions. MCS refers to equipment that must be hardened to perform missions specified to be accomplished during or after exposure to a HEMP environment.

Similar definitions could be developed for a COTS application for E3 risk assessment purposes.

A promising methodology of defining criticality is by creating a "zoning matrix" of EME categories based on the platform EME (as shown in Table 4 below) to create EMC requirements by group with which to conduct the final risk assessment. This is an actual example provided courtesy of the UK Aircraft Carrier Alliance. It defines equipment criticality levels (1* through 5) and EME Zones, resulting in categories A through E that define a minimum level of acceptable EMC performance.

Criticality Versus EME Zones	1*	1	2	3	4
Above Decks Above Bridge Roof	**A**	**A**	**A**	**A**	**A**[1]
Above Decks Below Bridge Roof	**B**	**B**	**B**	**B**	**D**
Below Decks High EME	**C**	**C**	**C**	**D**	**D**
Below Decks Low EME	**C**	**C**	**C**	**E**	**E**

Table 4 – Shipboard Example of Criticality vs. EME Zones

Zones would equate to (based on the CVF EMC Policy CVF-00005386 specifying four EME controlled zones):

– Above Decks, Above Bridge Roof Zone > 2000 V/m

– Above Decks, Below Bridge Roof Zone < 200 V/m

– Below Decks, High EME Controlled Zone < 10 V/m

– Below Decks, Low EME Controlled Zone < 3V/m

EMC Requirements (Groups A to E)

Note: these groups have been adapted for US DOD based on the original material from UK Defstan 59-411.

Group A-: The Electromagnetic Environment (EME), which these systems/equipments are likely to be located within, will be defined in MIL-STD-464C, MIL-STD-461F Above Deck Limits, MIL-HDBK-235, and for NATO EMEs, AECTP-258/, requirements will be applicable to the Group A systems/equipments also.

Group B-: MIL-STD-461F Above Deck Limits, requirements will be applicable to the Group B systems/equipments.

Group C-: MIL-STD-461F Below Deck Limits, requirements will be applicable to the Group C systems/equipments.

Group D-: EU Directive 89/336/EEC requirements, with the levels explained in BS EN 61000-6-2 and BS EN 61000-6-4 are applicable as a minimum to the Group D equipments. Group D equipments will be required to have been CE Marked or Wheel Marked certified.

Group D equipments, which are located in the Above Decks EME, will require evidence of acceptable performance levels achieved while exposed to the more severe EME. Those Group D equipments that are located in the Below Decks High EME Zone may require additional EM protective design measures to mitigate the risk of not achieving an acceptable level of EMC.

Group E-: EU Directive 89/336/EEC requirements, with the levels explained in BS EN 61000-6-1 and BS EN 61000-6-3 are applicable as a minimum to the Group E equipments. Group E equipments will be required to have been CE Marked or Wheel Marked certified.

Group E equipments that are located in the Below Decks High EME Zone may require additional EM protective design measures to mitigate the risk of not achieving an acceptable level of EMC.

While this is an example of shipboard EME criticality zones, a similar table can be produced for any platform/operational EME such as a forward deployed ground vehicle or

When determining the applicable EM environments and requirements, it is necessary to recognize possible operational restrictions that may be acceptable and to potential failure modes. A minimum separation between a COTS system and a potential interference source may be acceptable if the separation does not significantly restrict operations during deployment; or possibly certain failure modes are not mission or safety critical and a lesser degree of hardening of a COTS installation is acceptable. Additional cost of testing non-critical systems is a small price to pay to ensure systems operate safely during critical or battle conditions without jeopardizing the ship's mission.

Any operational restrictions, minimum separations, etc. should be formally documented by the Equipment Program Office based on recommendations from the program E3 engineering technical authority, as well as agreeing on the details of the scenarios to be used in the risk assessment analyses. Similarly, the frequency of occurrence of a particular environment may be sufficiently rare to allow it to be ignored or be considered only relevant to safety critical failure modes (e.g. for a direct lightning strike, some systems may only be required to remain safe but not necessarily suitable for service). Again the detail of the requirement needs to be agreed to by the Program office and the E3 technical authorities.

B. Summary

The previous paragraphs describe a variety of environments and EME and EMC requirements that should be considered in the use of COTS, because COTS are not typically designed for the rigorous military EME. All equipment, COTS included, will be expected to perform effectively and not cause E3 degradation or damage to any equipment it operates near. Although there are different environments for different situations, it may be necessary to look at only the worst case environments when considering the use of COTS in a military EME. For example, one would not manufacture an aircraft that was compatible with the EME in flight but not compatible with the airport EME. The remainder of this document focuses on a process by which to compare subsystem/equipment EMC type requirements that COTS are typically designed to against MIL-STD-461, which represents the requirements that the DOD would typically impose.

IV. Spectrum Supportability

DODI 4650.01 establishes DOD policy for management and use of the EM spectrum and defines procedures for obtaining required equipment spectrum certification (ESC). As of January 2009, it also requires DOD Components acquiring spectrum-dependent systems to perform spectrum supportability risk assessments (SSRAs). An SSRA is an evaluation performed by the DOD Component on *all spectrum-dependent systems, INCLUDING COTS,* to identify and assess *EM spectrum* and *E3* issues that can affect the required operational performance of the system. These risks are reviewed at acquisition milestones and managed throughout the system's lifecycle. Specific task and data requirements for the conduct of SSRAs are still emerging but your service Frequency Management Office can provide guidance on the basic requirements.

Spectrum Supportability, a relatively new term in the spectrum management and use area, is an assessment as to whether the electromagnetic spectrum necessary to support the operation of a spectrum-dependent equipment or system during its expected life cycle is, or will be, available. A Spectrum Supportability Risk Assessment requires:

- Equipment Spectrum Certification,
- Host Nation Spectrum Supportability Assessment (including US&P)
- EMC Analyses to determine possible EM interactions requiring further analysis

Equipment Spectrum Certification (ESC) Compliance is a statutory requirement for S-D systems, based on US Codes, Public Law and OMB guidance that basically states:

1. You cannot use the EM spectrum without obtaining certification and a frequency assignment to operate, and
2. You cannot spend DOD/public money to buy or build a system unless you know that it can obtain spectrum supportability.
3. It applies to any S-D equipment used by the DOD and does not differentiate between COTS and DOD developed systems.

The request for ESC, called the DD form 1494, Application for Equipment Spectrum Certification, is the vehicle by which certification is achieved and is also used for implementing Host Nation Coordination (HNC) and ascertaining frequency supportability within the territories of foreign nations. NTIA now requires the use of the EL CID form/format for submission of United States Government (USG) ESC requests. In OCONUS operations, the use of the spectrum for U.S. operations is by permission of the Host Government and is formalized in an agreement between the U.S. and the Host Government. To ensure EMC, the Host Government, in most cases requires the U.S. to supply data concerning the S-D equipments, E3, to include inland spectral plots, and equipment characteristics from a spectrum usage standpoint. *There are no exceptions for commercial off-the-shelf (COTS), non-developmental item (NDI), receive-only, or Electronic Warfare (EW) systems when the equipment, system or subsystem is to be operated outside the United States by the US DOD.*

Spectrum Supportability and the Spectrum Supportability Risk Assessment provide a documented plan/report to achieve positive SS Determination and also document details of the following for each piece of RF Spectrum Dependent equipment, system or subsystem:

- J/F 12's for each RF piece of equipment
- Status of Host Nation Coordination
- Known Spectrum Supportability issues
- Potential Operational impact of known spectrum supportability deficiencies, particularly in foreign countries
- Program Risk (R/Y/G) for each RF system, a spectrum supportability Risk summary, and Risk Mitigation plans for spectrum supportability issues.
- An assessment of spectrum supportability for acquisition Milestones

Spectrum Certification is but one element of the risk assessment process but not the main focus of this guidance document. Additional details on the ESC process and requirements to achieve spectrum certification are provided at Appendix B.

V. Evaluate COTS EM Performance and Conduct Gap Analysis

Military and commercial EMC standards are similar in that both are concerned with controlling emissions to and from surrounding equipment as well as identifying EM susceptibilities of the equipment. That is where the similarities end. Unlike the commercial environment, the military environment contains heavy concentrations of equipment in a confined area, high powered transmitters, and very sensitive receivers. This means that "mutual compatibility" between equipment is likely to pose greater problems in military environments, and the requirements for EMC will be harder to meet. "Equipment used in the military environment can often be classified as "mission critical", "mission essential" or even "safety critical". For military applications, lives can depend on electromagnetic compatibility between numerous electromagnetic devices in a small area. This characteristic is not typically present in commercial equipment and uses.

In the United States, EMI requirements on general types of electronics were first introduced by the FCC in 1979 for "computing devices" in the Code of Federal Regulations (CFR) 47, Docket 20780. The requirements used today are essentially the same and are limited to conducted emissions on alternating current (AC) power interfaces and radiated emissions. There are two sets of limits, one for residential areas and a second for industrial areas. Separate FCC requirements in CFR 47, Part 18, are applicable to industrial, scientific, and medical (ISM) equipment which intentionally use RF energy in their basic operation. Requirements for both Part 15 (also called low-power and non-licensed devices) and Part 18 devices are limited to radiated and conducted emission controls that are dependent on the characteristics of the RF source. The FCC does not yet mandate immunity (susceptibility) requirements for general electronics thereby increasing the risk to the DOD of using FCC approved part 15 or part 18 devices. Refer to Appendix A – EMC Compliance Requirements for a more detailed discussion of FCC and European processes. The European Union, on the other hand, requires equipment sold in Europe to meet both emission and immunity requirements. US manufacturers who wish to sell their products in Europe must meet a variety of these requirements. Member states of the European Union have accepted and are regulated by the Electromagnetic Compatibility (EMC) Directive 2004/108/EC and the Radio & Telecommunications Terminal Equipment Directive (R&TTE). These directives are intended to guarantee the free movement of apparatus and create an acceptable electromagnetic environment in the Community territory. In meeting the requirements of either directive, a Declaration of Conformity has to be created by the manufacturer, a CE mark affixed (most electronic equipment), and a technical file assembled that should include any test reports, data, etc. related to compliance with EMI requirements.

Obtaining evidence of EMC compliance is one of the major challenges of the risk assessment process. A CE Marked device indicates that the manufacturer or supplier has declared conformity with either the earlier EU EMC Directive 89/336/EEC for apparatus placed on the market up until 20 July 2007, or has declared conformity with the current EU EMC Directive 2004/108/EC for apparatus placed on the market since 20 July 2007. For equipment already placed on the market prior to 20 July 2007, the existing declaration of compliance with 89/336/EEC remains valid for a two-year transition period until 20 July 2009. After 20 July 2009, all equipment must comply with 2004/108/EC.

The CE mark on a piece of electronic equipment means that the manufacturer declares that the product meets the EU requirements for that product category. However, it may or may not meet the EU EMC Directive depending on what is noted in the Declaration of Conformity. If the device is declared in compliance with the EMC directive then a Technical File must be prepared that includes information on what EMC standards were applied, to what standard it was tested , and the test results. But buyers beware; manufacturers are allowed to “self declare” compliance with the EMC Directive although there may not be any actual data to review.

Figure 2 – Gap Analysis Process presents the major elements for conducting an effective comparison between military and commercial standards. This analysis identifies and compares the gaps in an effort to ensure all differences are identified and addressed before acquiring COTS equipment for military applications. It is a guide and should be used as such. Each step of the flowchart is examined in more detail below.

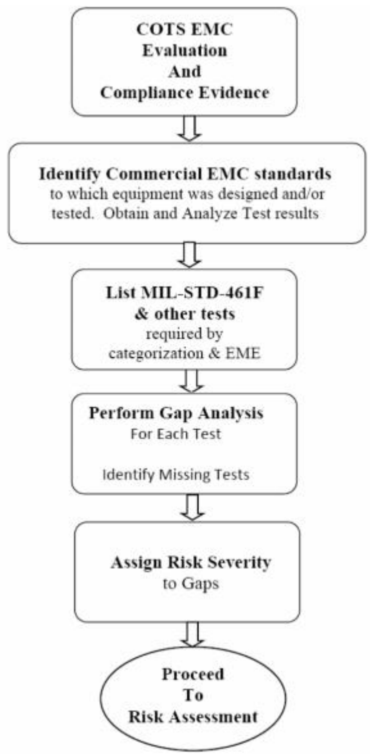


Figure 2 - Gap Analysis Process

A. Identify Commercial EMC standards/ Obtain & Analyze data

The gap analysis process identifies the shortfalls between the commercial tests required/performed on the equipment and the tailored military EMC/EMI requirements on the equipment in its intended operational environment. In order to achieve this, the commercial EMC standards, test methods and limits applied to the COTS equipment must be identified and compared to the military standard, test methods and limits that represent the environment in which the military equipment is to be operated. The first stage is therefore to identify the commercial EMC/EMI requirements, standards, test methods and limits applied to the COTS equipment (frequency ranges, limits, CE/RE/CS/RS test types, etc.), either for design and/or test purposes and the actual tests performed

Step one is to identify the Commercial EMC standards to which equipment claims compliance and to obtain and analyze any available test data. Create a list of commercial standards that the COTS equipment has been tested to and verified as per the Declaration of Conformity and/or test reports supplied by the manufacturer. During this exercise, one must ensure the test reports reflect the testing of the whole system and not just a portion of the system. An example would be a commercial test report for a radar system which might reflect the test results performed on the control unit only and not the antenna and/or visual display component which make up the system. Therefore, the test report is only good for a part of the system. This assumes that the antenna is on the mast, the control unit below deck, and the visual display component is on the bridge. In this scenario, it is suggested that an analysis needs to be performed on each piece of the system. The amount of testing of a COTS subsystem that may be reduced can be based on the actual location of the pieces of the system.

To evaluate the manufacturer's equipment testing, you should assemble all official EMC test data and reports (**from the manufacturer**) that were needed to:

- FCC mark a product for US consumption and/or,
- Self Declare via Declaration of Conformity (FCC/EU),
- Other relevant test results from a certified lab (US) or notified body (EU)

Note: Reports may reflect actual testing on another product. If applicable, request a copy of the engineering justification for grandfathering the system under another product's test results.

See Appendix A for more information on CE Mark and FCC compliance requirements and how to obtain test data. Included in Appendix A is a generic questionaire that might be used to gather pertinent EMC data on a COTS item.

B. List MIL-STD-461F Required/Desired Tests

Compile a list of ***tailored*** tests from MIL-STD-461F that reflect the minimum desired test requirements that the COTS equipment must meet based on the equipment categorization and EME definition developed previously (Section III). The Navy's EM-ARTT (www.em-tartt.us) is a database tool that can help define EMI requirements based on system technical parameters, location, and use. EM-TARTT is strictly for shipboard applications. Within this document, EM-TARTT results pertain only to the examples presented herein. To learn more about EM-TARTT refer to Appendix H.

Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations	Requirement Applicability																	
	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS106	CS109	CS114	CS115	CS116	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	A	S	S	S	A	L	A	S	A	A	A	L	A	A	L
Submarines	A	A	L	A	S	S	S	A	L	A	S	L	A	A	L	L	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S			A	A	A	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S			A	A	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S			A	A	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S			A	A	A		A	L		A	
Ground, Army		A	L	A	S	S	S			A	A	A		A	L	L	A	
Ground, Navy		A	L	A	S	S	S			A	A	A		A	L	A	A	L
Ground, Air Force		A	L	A	S	S	S			A	A	A		A	L		A	

Legend:
A Applicable
L Limited as specified in the individual sections of this standard
S Procuring activity must specify in procurement documentation
Requirement is not applicable.

Table 5 - Applicability of MIL-STD-461F Test Methods

(Per MIL-STD-461F Table 5)

Table 5summarizes the applicability of MIL-STD-461F EMI requirements for equipment and subsystems intended to be installed in, on, or launched from various military platforms or installations. Refer to MIL-STD-461F for specifics on the use of the table and the legend definitions.

Unfortunately, it's not as simple as applying the MIL-STD-461F tests from the applicability matrix but that's a good starting point. When defining an acceptable set of EMI control requirements for a COTS item, the previously defined EME, the equipment categorization exercises discussed in Section III and the determination of equipment and platform criticality must be taken into account. All these factors contribute to the definition and **tailoring** of specific MIL-STD-461F (and other EMI control) requirements and tests that would ideally apply in the risk assessment process. An in-depth discussion of tailoring MIL-STD-461F requirements is beyond the scope of this document but understanding how the requirements were tailored is an important part of the risk assessment process. Information on tailoring EMI requirements is available from DOD service EMC organizations and experts. Below is an example from a Terma Scanter Radar COTS installation which compares the desired and actual EMI requirements.

Terma Scanter FFG Install	Desired MIL-STD-461	Associated EU Commercial Std	From Test Reports	Tailored MIL-STD-461 Via EM-TARTT***
Conducted Emissions	CE101 CE102 CE106	CISPR 11 EN 55022 EN 61000-3-2 EN 61000-3-8 EN 61000-6-3 EN 61000-6-4	EN 61000-3-2 EN 61000-3-3 * EN 50081-1 EN 55022	CE102
Radiated Emissions	RE101 RE102 RE103	CISPR 11 EN 55022 EN 61000-6-3 EN 61000-6-4	* EN 50081-1 EN 55022	RE101 RE102 RE103

Conducted Susceptibility	CS101 CS116	EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-12 EN 61000-4-13 EN 61000-4-16 EN 61000-4-25 EN 61000-6-2	EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-11 EN 61000-6-2 EN 50082-2	CS116
Radiated Susceptibility	RS101 RS103	EN 61000-4-3 EN 61000-4-5 EN 61000-4-6 EN 61000-4-8 EN 61000-4-9 EN 61000-4-10 EN 61000-4-20 EN 61000-4-25 EN 61000-6-2	EN 61000-4-2 EN 61000-4-3 EN 61000-6-2 ** EN 50082-2	RS101 RS103
* Replaced by BS EN 61000-6-3 ** Superseded BS EN 61000-6-2 *** EM TARTT used for shipboard examples only; specific tailoring shown in Table 6				

Table 6 - Terma Scanter 2001 - Example EMI Requirements Comparison

MIL-STD-461F and MIL-STD-464A Tailored Requirements for Terma Scanter 2001 (X-band)
Equipment Description: Surface Surveillance Radar System X/S band transceivers
Terma Scanter 2001 (X-band) is a Mission Critical New Acquisition COTS based system to be installed Below Deck and Topside on various AGOR-14 ship(s). The voltage requirements for this system is 230 volts, current is 1.52 amps and the system draws 0.35kVa. This system is GROUPED into Pulse Power, Intensional Radars and Categorized as a Navigation Radar. It does NOT contain a UPS, it does contain Sensor Leads, and/or it contains the following display types: CRT. Terma Scanter 2001 (X-band) also transmits at 9170MHz-9438MHz and Terma Scanter 2001 (X-band) receives at 9170MHz-9438MHz. The tailored MIL-STD-461F and MIL-STD-464A requirement are as follows:

Test	Test Title
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CS106	Conducted Susceptibility, Transients, Power Leads
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10Khz to 18Ghz.
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 2 MHz to 18 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 2Mhz to 40Ghz, skipping 9167 MHz to 9441 MHz.

Tailored Shipboard EMI Requirements from EM TARTT - Example

	CE101	CE102	CE106	CS101	CS103	CS106	CS109	CS114	CS115	CS116	RE101	RE102	RE103	RS101	RS103	RS104
All subsystems		X				X					X	X	X	X	X	
Antenna only	X	X				X		X			X	X	X		X	
Control Unit only	X			X		X		X			X	X			X	
Display only		X		X		X					X	X		X	X	
Display only- Below Deck		X		X		X					X	X		X	X	

Table 7 - Terma Scanter 2001 Example EMI Requirements

C. Perform Gap Analysis for Each Test

Gap Analysis is the most critical step in the evaluation process. ***Significant E3 engineering experience and operational understanding is a necessity for conducting these comparisons and applications.*** It would be ideal if simple, direct comparisons of particular commercial standards with MIL-STD-461 counterparts were possible. Unfortunately, comparisons are rarely straightforward and it is almost impossible to call a particular commercial standard a one-for-one replacement for a MIL-STD-461 test. The major difficulty is that ***there are truly very few 1 to 1 direct mappings between commercial standards and MIL-STD-461F test methods*** for a variety of reasons, such as the environment for which the standard was intended and by whom the standards were written.

ENGINEERING PRACTICE STUDY (EPS) 0178, March 2, 2001, *Results Of Detailed Comparisons of Individual EMC Requirements and Test Procedures Delineated in Major National and International Commercial Standards With Military Standard MIL-STD-461E,* is an excellent reference in comparing commercial to military standards. Even though it was published in 2001, the standard comparisons are still valid in identifying the gaps in testing between standards. The document is available in the DAU ACC EM and Spectrum Compliance SIA Library:

https://acc.dau.mil/CommunityBrowser.aspx?id=128255&lang=en-US

From EPS 0178, on the challenges of conducting the comparisons:

> *"4.3.3 Differences Between Commercial and Military Standards. For orientation purposes we itemize below the most significant differences between commercial and military standards.*
>
> *a) Requirements in the VLF range for submarines are unique because of critical dependence on the reception of sonar and VLF electromagnetic signals.*
>
> *b) There is a high concentration of electronic equipment aboard ships and other military platforms including emitters and sensitive receivers. For this reason, military radiated emission limits are more severe than corresponding commercial limits. The military also places high immunity requirements on devices exposed to nearby intentional emitters.*
>
> *c) The general availability of grounded conducting surfaces (ground planes) for mounting equipment on military platforms. Most commercial equipment (when it is light in weight or portable) is mounted on an ungrounded table top. However, this difference is not pervasive, e.g. floor mounted commercial equipment is frequently bonded to a ground plane.*
>
> *d) Some frequency ranges are more extensive in military requirements than they are in commercial requirements, hence if equipment is tested to meet commercial requirements, additional testing may be needed for military use*
>
> *These differences make it impossible to find commercial qualified equipment that is completely equivalent to one meeting military requirements. This means that a detailed analysis is required to determine the adequacy of equipment tested to commercial requirements to meet the requirements of a particular military environment."*

EPS 0178 Table 5.1 provides a high-level comparison matrix of commercial and military requirements and more detailed explanations of each comparison in Section 6. Annex A of EPS 0178 provides even more detailed discussions for E3 experts who have the skills necessary to apply the guide to specific procurements. It is highly recommended that the reader obtain and review EPS 0178 for more detail on the challenges of conducting these comparisons.

A Practical Paper, *Risk Analysis by the Use of Commercial Equipment in a Military Environment* by Henk A. Klok is another excellent and applicable reference. It provides a more global explanation of the difficulty of conducting standard comparisons from a European perspective. Mr. Klok discusses the differences between MIL-STD 461D/462D and civil EMI-requirements with respect to measurement methods, frequency range and limits. Rather than comparing individual tests, he groups tests into the four primary categories: CE, CS, RE and RS. He also discusses the electromagnetic environment on board Navy ships and evaluating the risk of using COTS equipment in that environment. A few of the assumptions made in the theoretical approach of the comparison are verified by using measurement data taken from commercial equipment. This paper and others are available in the DAU Acquisition Community Connection EM Spectrum Special Interest area at [acc.dau.mil](acc.dau.mil) (look for the Technical Articles section).

Table 8 chart is from the United Kingdom Ministry of Defence Standard, DEF STAN 59-411, Electromagnetic Compatibility Management & Planning. It can be used to identify many of the factors that affect test severity that apply to the equipment being evaluated.

Test Type	**EMC Gap Analysis Factors Affecting Test Severity** (Not all may be applicable)
Conducted Emissions	Scope of lines under test (power and/or signal, control) Frequency range Detector (average/peak/quasi peak) Measurement device (LISN/Current probe/AMN/ISN Measurement distance from EUT along cable Limit units (current/voltage) Circuit impedance for converting between current and voltage Limit level
Radiated Emissions	Frequency range Antenna test distance Extrapolation method Detector (average/peak/quasi peak) Test set up (ground plane/EUT height/Bonding) Limit units (current/voltage) Limit level
Conducted Susceptibility	Scope of lines under test (power and/or signal, control) Frequency range Modulation Coupling device (Current probe/Coupling Decoupling Network/Shield Injection) Coupling distance from EUT along cable Limit units (current/voltage) Circuit impedance for converting between current and voltage Calibration technique (CW/peak envelope/monitor open circuit/monitor in circuit) Limit level
Radiated Susceptibility	Frequency range Modulation Test set-up (ground plane/EUT height/Bording) Limit units (current/voltage) Calibration technique (CW/peak envelope/pre-calibrated volume/field monitored) Limit level
Transient Susceptibility	Scope of lines under test (power and/or signal, control) Peak (absolute) Voltage/Current (Impedance conditions) Peak (absolute) value or rate of rise Peak (absolute) Impulse - impulse equivalent maximum energy in a single polarity Rectangular Impulse - impulse equivalent of total energy Root action integral - total energy Time to peak value Frequency spectrum Calibration technique (pre-calibrated level/monitored in circuit) Differential or common mode coupling

Table 8 - EMC Gap Analysis Factors Affecting Test Severity

The final step in the gap analysis is to identify "missing" tests. In other words, what military EMI requirements are not reflected in the commercial tests that were conducted? List these additional (full or verification) tests that need to be considered and/or performed to verify COTS equipment's ability to meet EMC requirements in the defined military environment.

An example of a "missing test" might be a verification test which would be added because the "frequency range" scanned in a commercial standard is incomplete for a required military environment. As can be seen above in Table 8, "frequency range" occurs in all the different test types given. The reason is normally based on the high concentration of other equipment operating in the same frequency range in a military environment. The concern would be interference with other equipment. Remember, commercial standards are written for commercial applications and not military applications: that is why there is a gap between commercial and military standards.

Another example would be "limit levels." Table 8 reflects that all Test Types have "limit levels" associated factors affecting test severity. Depending upon the test, the commercial standard's limit level is normally less stringent because they do not take into consideration the close proximity and concentration of radiators and receivers in most military environments. Limit levels also reflect differences in test receiver bandwidths used in various radiated and conducted emissions tests. Different susceptibility (immunity) tests use different modulated signals as well. There are exceptions to the phenomena. Therefore, every gap should be examined and an engineering analysis conducted to determine it's specific application to the required equipment environment.

D. Assign Risk Severity to Gaps

Once the gaps between individual tests have been identified, they can each be assigned a risk rating of Low, Medium, or High depending on the extent of the assessed differences. The assignment of a risk rating is subjective but an attempt is made herein to provide a method to standardize the process as much as possible. As previously mentioned, the risk rating assignment is the responsibility of the Program Office, but E3 engineers should provide recommendations based on their professional experience conducting risk assessments.

The risk rating assigned to the gaps identified from the evaluation of the COTS EMC compliance evidence must be compared to the criticality of the COTS equipment and the criticality of the environment or platform in which the COTS equipment will be operated. ***This comparative analysis forms the basis for the final risk assessment***. Generally, the greater the criticality of the COTS equipment, the lesser the degree of susceptibility risk will be permitted to the COTS item. The greater the criticality of the environment or platform, the lesser the degree of emissions risk will be permitted to the environment or platform. This concept is summarized in Table 9, UK MoD and Defence Standard 59-411.

		Environment/platform criticality	
		Safety/mission critical	**Non-critical**
Equipment criticality	**Safety/mission critical**	Emission = Low Susceptibility = Low	Emission = Low to Medium Susceptibility = Low
	Non-critical	Emission = Low Susceptibility = Low to Medium	Emission = Low to Medium Susceptibility = Low to Medium
	NOTE High risk unacceptable for any combination without mitigation		

Table 9 - Guide to Minimum Acceptable Risk Resulting from EMC Gap Analysis

Table 9 talks to the ACCEPTABILITY of the risks. Where Emission and Susceptibility is listed as "Low", that means that the acceptability of undesirable EM emissions is Low (or high risk, in other words).

The risks identified in the gap analysis process must now be compared to the criticality of the COTS equipment and the criticality of the environment or platform in which the COTS equipment will be operated. Nil to Low risk will generally be acceptable. In some non-critical situations Low to Medium risk may be acceptable. In all cases a High risk is most likely unacceptable unless some mitigating action or additional testing is applied.

In the assignment of risk severity, it is useful to examine how the services define and categorize EMI problems encountered during testing. Consider the following:

- During EMV testing at the Naval Surface Warfare Center, Dahlgren Division, they define "susceptibility" as any RF induced response. If that response causes an unacceptable mission impact, then it is classified as a "vulnerability" which must be corrected. When they see an RF response to a test EME level, they will then find the threshold of vulnerability (ToV) for that problem. Knowing the ToV and the probable operational EME for the EUT allows them to discuss the mission impacts with the customer, who makes the final decision on mission impact.
- Naval Air Systems Command, E3 Test Definition of Deficiencies
    - Part I indicates a severe deficiency, the correction of which is necessary because it adversely affects one or more of the following: Airworthiness, mission capability, protection of classified information processing systems, crew safety, system functionality, and others
    - Part II indicates a deficiency that is less severe than Part I; in other words a deficiency that does not substantially reduce the capability of the aircraft or system to accomplish its intended mission. The correction of this deficiency will result in significant improvement in mission effectiveness, reliability, maintainability, supportability, or safety. Until the deficiency is resolved, significant operator compensation is required to achieve the

desired level of performance; however, the aircraft or system is still capable of accomplishing its intended mission with a satisfactory degree of safety and effectiveness.
    - Part III indicates a deficiency that is minor or appears too impractical or uneconomical to correct at this time.

The point of this discussion is that it is useful to develop and document a set of risk severity categories for the issues identified during the gap analysis process. The individual gaps identified can be treated as though they are EMI problem failures discovered during testing. Then they can be categorized in a manner similar to the EMI test failure categories above.

If there are missing tests, as discussed in the previous section, the lack of data by which to assess particular EMI requirements must be included in the risk assessment. One mitigation technique to rectify a lack of data in a specific area is obviously to conduct additional testing.

Table 10 provides a gross assessment of the acceptability of equipment that conforms to the most prevalent commercial standards for use on typical military platforms. It may represent a good starting point for a specific gap analysis effort but, in general, should be used only as a guide to the noted military platforms.

RISK

- L = Low Risk
- M = Moderate Risk
- H/N = High Risk, No Similar Commercial Requirement
- H = High Risk
- N/A = Military Requirement that's not applicable to this platform

LEGEND

CS101	CE101	RE101	RS101
CS109	CE102	RE102	RS103
CS114	CE106	RE103	RS105
CS115			
CS116			

Standards Qualification Status / Application Platform	DO-160D				INTERNATIONAL (IEC/CISPR)				NATIONAL (FCC PART 15/ ANS C63)			
SURFACE SHIPS	H	N/A	H	H	H	N/A	H	H	H	N/A	H	H
	H	M	M	H	H	M	H	H	H	M	M	H
	M	H	H	H	H	M	H		H	M	M	H
	N/A				N/A				N/A			
	H				M				H			
SUBMARINES	H	H/N	H/N	H/N	H	H	H	H	H/N	H/N	H/N	H/N
	H/N	M	M	M	H	H	H	H	H/N	L	H	H/N
	M	H/N	H/N	H/N	H	H	H	M	H/N	H/N	H/N	H/N
	H/N				M				H/N	See Note 1.		
	H/N				M				H/N			
AIRCRAFT, ARMY (Including Flight Line)	M	H	H	H	H	H	H	H	H	H	H	H
	N/A	L	M	M	N/A	M	H	M	N/A	M	H	H
		H	H	H	M	H	H	M	H	H	H	H
	H				M				H			
	H				M				H			
AIRCRAFT, NAVY	M	H/N	H/N	H/N	H	M	H/N	H/N	H/N	H/N	H/N	H/N
	N/A	M	M	M	N/A	M	H/N	M	N/A	M	M	H/N
	L	N/A	N/A	N/A	M	N/A	N/A	M	H/N	N/A	N/A	H/N
	H/N				H/N				H			
	M				M				H/N			
AIRCRAFT, AIRFORCE	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	H	M	N/A	M	H	N/A
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
SPACE SYSTEMS (Including Launch Vehicles)	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	M	M	N/A	M	M	H/N
	L	H/N	H/N	N/A	L	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
GROUND, ARMY	M	N/A	N/A	H	H	N/A	N/A	H	H	N/A	N/A	H
	N/A	L	M	M	N/A	M	H	H	N/A	M	H	H
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			
GROUND, NAVY	H	N/A	N/A	N/A	H	N/A	N/A	N/A	H	N/A	N/A	N/A
	N/A	M	M	M	N/A	M	H	M	N/A	M	M	H
	M	H	H	H	H	M	H	L	H	M	M	H
	N/A				N/A				N/A			
	H				M				H			
GROUND, AIR FORCE	M	N/A	N/A	N/A	H	N/A	N/A	N/A	H/N	N/A	N/A	N/A
	N/A	L	L	L	N/A	M	H	M	N/A	M	H	N/A
	L	H/N	H/N	N/A	M	H	H	N/A	H/N	H/N	H/N	N/A
	H/N				M				H/N			
	H/N				M				H/N			

RISK

- L = Low Risk
- M = Moderate Risk
- H/N = High Risk, No Similar Commercial Requirement
- H = High Risk
- N/A = Military Requirement that's not applicable to this platform

LEGEND

CS101	CE101	RE101	RS101
CS109	CE102	RE102	RS103
CS114	CE106	RE103	RS105
CS115			
CS116			

Table 10 - Assessment of Commercial Standards vs. MIL-STD-461

(Per EPS0178, Table 5-1)

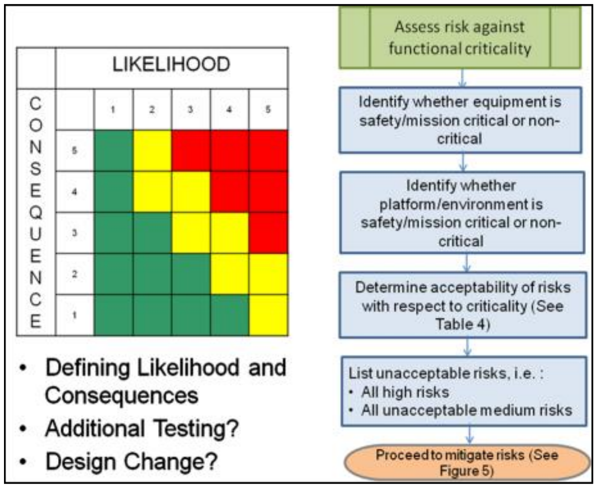
The matrix is formatted in both color and alphabetic criteria to provide the user with a rapid snapshot of the EMI posture of the particular equipment/systems they are considering purchasing for use on various military platforms. The commercial standards are divided into these categories: DO-160D, International, and National. The five Risk Categories are:

- Acceptable with a low risk (L, green)
- Acceptable or moderate risk (M, black)
- Unacceptable, high risk (H, red)
- Unacceptable, high risk, there is no similar commercial requirement (H/N, red)
- No military requirement for this platform (N/A, blue)

Each intersection of a row with a column consists of fourteen sub-blocks. As per the legend at the left of the table, these sub-blocks represent, on a column-by-column basis, the Conducted Susceptibility, Conducted Emission, Radiated Emission, and Radiated Susceptibility information, respectively. For example, the intersection of the row for Navy Ground and National standards shows that for the 14 tests called out in MIL-STD-461, five do not apply to this platform, and nine do. For those that apply, four tests are moderate risk and five tests are high risk. For requirements according to DO-160D, the numbers are similar; but the tests at risk change somewhat (the CS114 and RS103 requirements are now at moderate rather than high risk and the CE106 and RE103 requirements are at high risk).

To reduce or eliminate the initially stated “risk” level given in Table 10 a technical analysis must be made of the differences in instrumentation, measuring technique and limits and evaluate their consequences.

VI. RISK ANALYSIS



The overall program risk can now be documented based on all the previous analysis and information. Risk analysis is the activity of examining each identified risk to refine the description of the risk, isolate the cause, determine the effects, and aid in setting risk mitigation priorities. It refines each risk in terms of its likelihood, its consequence, and its relationship to other risk areas or processes. This Guidance Document doesn't present any new ideas relative to Risk Analysis; It simply attempts to apply existing Risk Analysis methodology to the particular case of COTS E3 integration.

Effective risk management approaches generally have consistent characteristics and follow common guidelines regardless of program size. Effective risk management approaches have the following risk management characteristics. Refer to Risk Management Guide for DOD Acquisition, sixth edition (Version 1.0), Aug 2006.

- Feasible, stable, and well-understood user requirements, supported by leadership / stakeholders, and integrated with program decisions
- A close partnership with users, industry, and other stakeholders
- A planned risk management process integral to the acquisition process, especially to the technical planning (SEP and TEMP) processes, and other program related partnerships
- Continuous, event-driven technical reviews to help define a program that satisfies the user's needs within an acceptable risk
- Identified risks and completed risk analyses
- Developed, resourced, and implemented risk mitigation plans
- Acquisition and support strategies consistent with risk level and risk mitigation plans
- Thresholds and criteria for proactively implementing defined risk mitigation plans
- Continuous and iterative assessment of risks
- The risk analysis function independent from the PM
- A defined set of success criteria for performance, schedule, and cost elements; and
- A formally documented risk management process

It is our intent that this guidance herein assists in the implementation of an effective EMC risk management program for COTS use.

Risk Analysis begins with a detailed study of the risks that have been identified, in our case, the risk of deploying COTS with identified gaps between the commercial EMI/EMC testing conducted and the desired military EMI/EMC requirements. The objective is to gather enough information about the platform or system installation to judge the likelihood and the consequences if the risk occurs. So, what is required to complete the risk analysis after the gap analysis is completed? At a minimum, the following information is required:

- A method to categorize the mission criticality of the installation including the following considerations (not all inclusive)
  - Equipment vs. Platform criticality
  - Safety vs. Mission Criticality
- Definitions of:
  - Severity (Consequence) of EMI Problem
  - Likelihood (Probability) of EMI Problem

Standard risk analysis tasks have been tailored to include steps that:

- Develop probability and consequence scales by allocating consequence thresholds against a predefined criticality matrix;
- Assign a probability of occurrence to each risk using the developed criteria;
- Determine consequence in terms of performance impact; and
- Document the results to the program.

A. Criticality (Equipment and/or Platform)

The subject of criticality (of equipment) in the categorization discussion earlier has been broached. The criticality of the platform on which the COTS equipment will be installed must also be considered. The combined criticality of the COTS equipment installed on a particular platform in a particular EME should be defined relatively early in the COTS E3 Risk Assessment process. It is at this point in the process, following the Gap Analysis, that the assigned criticality must be factored into the overall risk assessment process. The Risk Acceptability presented in Table 11 is one way to do this.

		Environment/platform criticality	
		Safety/mission critical	**Non-critical**
Equipment criticality	**Safety/mission critical**	Emission = Low Susceptibility = Low	Emission = Low to Medium Susceptibility = Low
	Non-critical	Emission = Low Susceptibility = Low to Medium	Emission = Low to Medium Susceptibility = Low to Medium
	NOTE High risk unacceptable for any combination without mitigation		

Table 11 - Guide to Acceptability of Risk Resulting from EMC Gap Analysis

Table 11 talks to the ACCEPTABILITY of the risks. Where Emission and Susceptibility is listed as "Low," that means that the acceptability of undesirable EM emissions is Low (or high risk, in other words). To turn that around and redefine the table in terms of actual risk levels, the table would look like this (Table 12):

		Environment/platform Criticality	
		Safety/Mission Critical	Non-Critical
Equipment Criticality	Safety/Mission Critical	Emissions = High Risk Susceptibility = High Risk	Emissions = Med to High Risk Susceptibility = High Risk
	Non-Critical	Emissions = High Risk Susceptibility = High to Med Risk	Emissions = Medium to Low Risk Susceptibility = Medium to Low Risk
	Note: High Risk unacceptable for use in any combination without mitigation		

Table 12 - Guide to Risk Rating Resulting from EMC Gap Analysis

If the COTS item is considered non-critical and installed on a non-critical platform (the lower, right hand quadrant) the unacceptable or out-of-specification emissions and susceptibilities discovered during the gap analysis phase would be considered low to medium performance risk. After that, the details of the installation and the circumstances of the equipment use would have to be examined carefully to determine the overall acceptability of the installation or whether some sort of mitigation is required.

But what is the effect of criticality on the overall Risk Assessment. The more critical the COTS item or the platform on which it is installed is deemed to be, the more the assessment will be driven to the High Risk areas for known EMC gaps. The simplest methodology might be for the equipment to be deemed either mission critical or not mission critical (as noted in Table 12). There would then only have to be two risk categories defined, one for each designation. The effect of criticality is graphically represented in Figure 3 below.

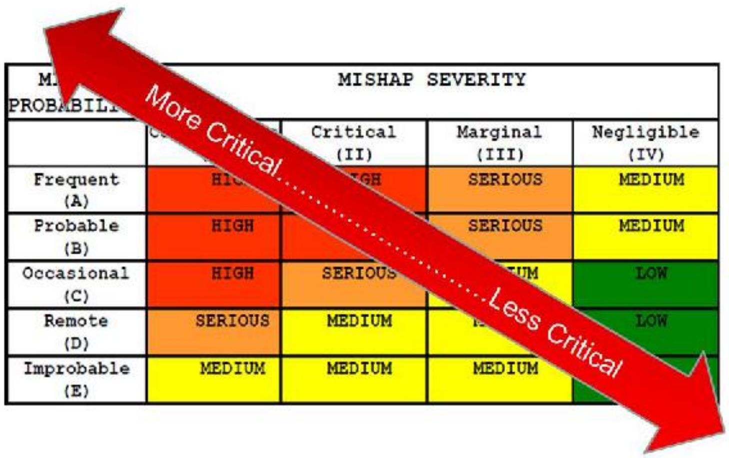


Figure 3- Effect of Criticality on Risk Assessment

B. Standard Definitions of Likelihood (Probability) and Severity (Consequence)

The starting point for all risk related definitions will be MIL-STD-882, System Safety so that standard risk assessment terminology and methodology are being used. Where it is useful to E3-related purposes, items can be tailored to be more E3-oriented. The standard four-by-five Risk Matrix will be tailored to a simpler three by three configuration. Working group discussions have determined that EMI probabilities and severities are relatively "cut and dry" so that less fidelity is needed in the actual risk matrix than the standard setup. T he standard matrix structure will be examined before tailoring down to the three by three model.

Mishap severity categories are defined to provide a somewhat standardized qualitative measure of the most reasonable credible mishap resulting from personnel error, environmental conditions, design inadequacies, procedural deficiencies, or system, subsystem, or component failure or malfunction. Suggested mishap severity categories are shown in Table 13 below.

System Safety Risk Matrices - MIL-STD-882

MISHAP PROBABILITY	MISHAP SEVERITY			
	Catastrophic (I)	Critical (II)	Marginal (III)	Negligible (IV)
Frequent (A)	HIGH	HIGH	SERIOUS	MEDIUM
Probable (B)	HIGH	HIGH	SERIOUS	MEDIUM
Occasional (C)	HIGH	SERIOUS	MEDIUM	LOW
Remote (D)	SERIOUS	MEDIUM	MEDIUM	LOW
Improbable (E)	MEDIUM	MEDIUM	MEDIUM	LOW

Table 13 - Risk Levels (High, Serious, Moderate and Low)

Threat severity or consequence definitions from the DOD Risk Management Guide (based on MIL-STD-882) are shown below and include cost and schedule impacts. The level and types of consequences of each risk are established using criteria such as those described in Table 14. A single consequence scale is not appropriate for all programs, however. For the purposes of this document, only a technical performance definition for risk severity will be used. In addition, since a three by three matrix was developed, the three highlighted definitions in Table 14 below will be used.

Consequence

Level	Technical Performance	Schedule	Cost
1	Minimal or no consequence to technical performance	Minimal or no impact	Minimal or no impact
2	Minor reduction in technical performance or supportability, can be tolerated with little or no impact on program	Able to meet key dates. **Slip < _*_ month(s)**	Budget increase or unit production cost increases. **< _**_ (1% of Budget)**
3	Moderate reduction in technical performance or supportability with limited impact on program objectives	Minor schedule slip. Able to meet key milestones with no schedule float. **Slip < _*_ month(s)** **Sub-system slip > _*_ month(s) plus available float.**	Budget increase or unit production cost increase **< _**_ (5% of Budget)**
4	Significant degradation in technical performance or major shortfall in supportability; may jeopardize program success	Program critical path affected. **Slip < _*_ months**	Budget increase or unit production cost increase **< _**_ (10% of Budget)**
5	Severe degradation in technical performance; Cannot meet KPP or key technical/supportability threshold; will jeopardize program success	Cannot meet key program milestones. **Slip > _*_ months**	Exceeds APB threshold **> _**_ (10% of Budget)**

* Tailor for program in month(s) ** Tailor for program in whole dollars

Table 14 - Levels and Types of Consequence Criteria

(Per Figure 4, Risk Management Guide for DOD Acquisition, 6th Edition)

After Consequence (Severity), the probability that the problem occurs must be defined. Mishap probability is the statistical likelihood that a design or procedural hazard will occur during the planned life expectancy of the system. It can be described in terms of potential occurrences per unit of time, events, population, items, or activity. Assigning a quantitative mishap probability to a potential design or procedural hazard is generally not possible early in the design process. At that stage, a qualitative mishap probability may be derived from research, analysis, and evaluation of historical safety data from similar systems. Supporting rationale for assigning a mishap probability is documented in hazard analysis reports. Suggested qualitative mishap probability levels are shown in Table 15.

Description*	Level	Specific Individual Item	Fleet or Inventory**
Frequent	A	Likely to occur often in the life of an item, with a probability of occurrence greater than 10^{-1} in that life.	Continuously experienced.
Probable	B	Will occur several times in the life of an item, with a probability of occurrence less than 10^{-1} but greater than 10^{-2} in that life.	Will occur frequently.
Occasional	C	Likely to occur some time in the life of an item, with a probability of occurrence less than 10^{-2} but greater than 10^{-3} in that life.	Will occur several times.
Remote	D	Unlikely but possible to occur in the life of an item, with a probability of occurrence less than 10^{-3} but greater than 10^{-6} in that life.	Unlikely, but can reasonably be expected to occur.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced, with a probability of occurrence less than 10^{-6} in that life.	Unlikely to occur, but possible.

Table 15 - Suggested Mishap Probability Levels

(Per MIL-STD-882D Table A-II)

As was done with risk consequence, three of the probability categories will be employed (shaded in green in Tables 14 and 15) to construct our three by three risk matrix. It makes sense that EMI problems will either be very repeatable within a given set of circumstances, or that it will be very unlikely to happen at all. For intermittent type EMI problems, there is one probability level in the middle.

C. The Risk Matrix

Once the probabilities and likelihood criteria are defined, the final step is to construct the Risk Matrix for a particular piece of COTS equipment, given a particular criticality grouping based on its planned use. The Risk Matrix is a standard risk analysis output documented in DOD Systems Engineering materials (DOD Risk Management Guide (based on MIL-STD-882), providing a matrix of likelihood vs. consequence of a particular event, with the intersections defining the level of risk for that event. Our immediate challenge is that defining the likelihood that EMI will occur and the consequences of an EMI event is very subjective. All the definitions should be tailored for E3 related applications on a particular program.

As previously mentioned, the matrix has been limited to three by three to simplify the output. It is seen from the DOD Guide material that high level program risks (like percentage of budget) are considered. For the case of EMI and COTS however, the concern is with proper operation of the equipment. When executing the risk process and developing the matrix, detailed documentation of the thought processes and assumptions on these items is a must.

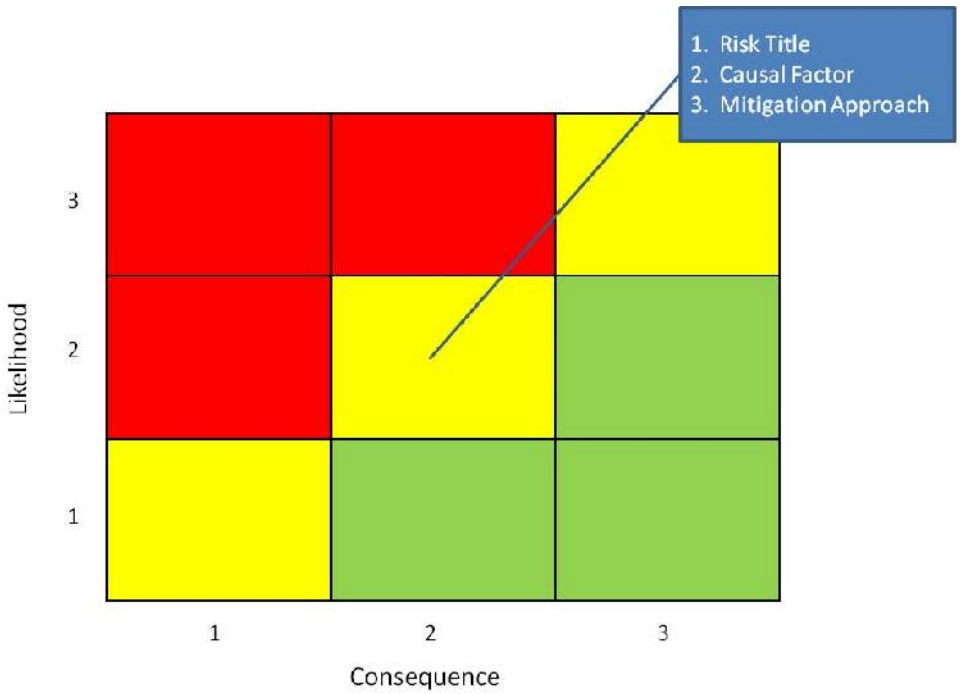


Table 16 – Modified 3x3 Risk Reporting Matrix

Keeping to the standard convention for a Risk Reporting matrix, three key elements need to be provided:

1. A brief description of the risk;
2. A brief description of the root causal factor(s) for the risk and;
3. The proposed/planned mitigations that address the source(s) and effect(s).

It is standard practice to create Risk Assessment Values to plug into the matrix, allowing a relative ranking of all the risks encountered. An example of a table of such values based on MIL-STD-882 conventions is shown in Table 17.

SEVERITY PROBABILITY	Catastrophic	Critical	Marginal	Negligible
Frequent	1	3	7	13
Probable	2	5	9	16
Occasional	4	6	11	18
Remote	8	10	14	19
Improbable	12	15	17	20

Table 17 - Example Mishap Risk Assessment Values

(Per MIL-STD-882D, Table A-III)

Once again, applyingthat concept to the 3x3 matrix convention is applied, a Risk Assessment Values table can be developed that would look something like Table 18 below.

Mishap Risk Assessment Value	Risk Category	Risk Acceptance Level
1-3	High	Program Manager/PEO
4-6	Medium	Systems Engineering Lead
7-9	Low	As Directed

Table 18 - Example Mishap Risk Categories and Mishap Risk Acceptance Levels

(Based on our tailoring of MIL-STD-882D conventions)

A written explanation of what constitutes High (Red), Medium (Yellow), and Low (Green) risk levels is also useful in the production of the actual risk matrix to provide understandable boundaries for each level of risk. A recent example produced by a tri-service committee developing Spectrum Supportability Risk Assessment guidance is show below. Many of the same criteria used in each risk level can be modified and applied to the COTS E3 Risk Assessment process.

R

- **No certification or approved J/F-12 in the MCEB archived database**
- **Operating in the incorrect or non-allocated frequency band or significant SS issues are known to exist for this system/equipment**
- **No E3 or, as a minimum, EMC and EMI studies completed, planned or anticipated; known mitigation measures will impact operational deployment and/or use in EME**
- **HNC process not started; operational and/or developmental use may be extremely limited and/or not permitted at all**
- **System will not likely receive HN spectrum support, or may be allowed to operate after lengthy bi-lateral negotiations with individual HNs.**

Y

- No certification or approved J/F-12 in the MCEB archived database, however similar equipment has been approved and is in the database
- System is operating in properly allocated frequency spectrum and ESC can be anticipated
- Requires minimal actions for ESC, i.e. Note-to-Holder or updated certification request
- E3/EMC studies funded/planned or completed with mitigation measures identified that will not adversely impact operations
- Minimum spectrum issues are known to exist for this equipment
- Operational and/or developmental use is anticipated to be supportable
- May receive HN spectrum support, but with numerous geographic, temporal, spectrum, or operational restrictions; spectrum use in a band may be restricted to a limited number of channels.

G

- Approved J/F-12 exists in the MCEB archived database (minimum Stage 2 for MS B)
- Requires no actions for spectrum support
- E3/EMC studies completed and compatible operations confirmed or acceptable mitigation measures identified that will not impact operations
- No SS issues are known to exist for this equipment in the intended operational area
- Operational and/or developmental use is or will be supportable
- High likelihood of receiving HN spectrum support to operate with few, or a minimum number of, possible spectrum or operational restrictions.

As will become evident in the example to follow, it takes a great deal of E3 engineering knowledge and program experience to apply all the previous risk guidance to an actual example.

Risk Matrix Example

Comment [b1]: Need to complete!

The following example of the proposed installation of a COTS surface search radar (TERMA SCANTER) aboard a Navy frigate (USS Simpson, FFG 56) will hopefully serve to provide an example of what the actual risk matrix looks like when completed. Bear in mind that the matrix is formatted to be easily briefed; there is a great deal of backup information that goes into the creation of the matrix and that should be kept available for reporting and presentation purposes. That backup information, test reports, spectrum certification documentation, etc. is not contained herein, but listed so that the reader can see what types of documentation was used in the analysis.

Manufacturer Data Sheet

Transceiver Controller

- Local or remote set-up and control of the transceiver
- Sector transmission, 4 sectors
- Storage of 16 operator-defined profiles
- Control of on-board BITE on the individual modules
- Remote control via Serial Interface or LAN

Receiver

- Low Noise Receiver: Typical 2 dB, overall system: 3.5 dB, max system: 4.5 dB
- Receiver Chain: Modified Logarithmic IF, 100 MHz
- Dynamic range: >125 dB
- Image rejection on RX mixer: ≥18 typically 20 dB

Transmitter

- Nominal Output Power: 25 kW (X-band), 30 kW (S-band)
- Transmitter frequency: Nominal 9375 MHz (X-band) Optional 9172 MHz, 9410 MHz, 9440 MHz, 9490 MHz
- Transmitter frequency for Frequency Diversity: 9170 MHz, 9438 MHz
- Transmitter frequency: Nominal 3050 MHz (S-band)
- Tx Pulse Shape: Fast rise (20 ns), fast fall time (30 ns)
- PRF: 400-8000 Hz, programmable
- PW: (40) 50 -1000 ns, programmable
- Stagger: 0,2,4,8 %, programmable
- Full transmitter performance during short pulse transmission

Signal Processing

Auto-adaptive Sensitivity Control

- Adaptation to changes in sea clutter by automatic adjustment of STC in a large number of individual cells in range and azimuth

Video Processor

- ADC: 80 MHz
- Digital FTC
- Sweep-to-sweep correlation
- 2-64 pulse azimuth integrator
- Digital, Analogue and Composite Video output

Frequency Diversity Processing

- Transmission on two frequencies. Transmitter power will be the total of two pulses, integrated non-coherently
- Target fluctuation reduced after integration of signals from independent pulses
- Time diversity, when using SWG antennas, enables de-correlation of sea clutter, thereby enhancing detection of small targets in situations with high Sea State
- Total system enhancement: Approx. 10 dB

Sea Clutter Discriminator

- Scan-to-Scan processing in 3 parallel channels for enhancement of small target detection

Built-in Power Supply and Antenna Control

Built-in frequency converter facilitates programmable antenna rotation rate.

Reliability

The system is designed to achieve an MTBF of 20,000 hours, facilitating installation on remote, un-manned radar sites

Installation data

Weight 45-55 kg
Width 513 mm
Height 900 mm
Depth 270 mm

Environmental specifications and approvals

Test	Conditions	Limits	Corresponding standard
Cold,	Storage	– 40° C	IEC 68-2-1, Test Ad
	Function	0 Deg C	IEC 945
Dry Heat	Storage	+70 Deg C	IEC 68-2-2, Test Bd
	Function	+55 Deg C	IEC 945
Protection	Function	IP 52	IEC Publication 529
EMC	Function		MIL-STD-461 EN 60945/A1
Out of band and spurious			ITU-R SM.1541 ITU-R SM.329-9

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e-mail: radar-sales@terma.com

Manufacturer Provided Test Results Immunity Tests Conducted and Results Passed All	
RF EM Fields	EN 61000-4-3:1996+A1
Conducted RF Interference	EN 61000-4-6:1996
Electrical Fast Transients	EN 61000-4-4:1995
Electrostatic Discharges	EN 61000-4-2:1995+A1
Voltage Dips and Interruptions	EN 61000-4-11:1994
Surge Transients	61000-4-5:1995

Manufacturer Provided Test Results Emissions Tests Conducted and Results Passed All	
EN 55022:1998, Class B	
Conducted emission, AC mains	CISPR 22:1997, Class B
EN 55022:1998, Class B	
Conducted emission, AC mains	CISPR 22:1997, Class B
Radiated electromagnetic field	
Mains Harmonic Current	EN 61000-3-2:2000
Induced mains voltage	EN 61000-3-3:1995+A1

Summary of comparison of commercial test results to MIL-STD-461E Test methods and limits and conclusions reached by E3 engineer:

Test Report – DANAK -Measurements of Radio Frequency Interference

- Radiated & Conducted – Controller Only Tested (no cables, monitor,etc.)
- Conducted, AC mains – not all measurements were below limit w/2.1 dB uncertainty.
- Radiated Electromagnetic Field - not all measurements were below limit w/2.6 dB uncertainty
- Data Sheet - states MIL-STD-461 & EN 60945/A1 "Environmental Specifications and Approvals
- CE101 to 61000-3-2 - 2.4 kHz to 10 kHz not scanned, limits differ
- CE102 to CISPR22 - 10 kHz-150 kHz not scanned, limits differ

Test Report – DANAK - Measurements of RFI (Susceptibility) Immunity

- System Tested - controller, cables, motor, monitor w/dummy loads
- CS114 to 61000-4-6 - 10 kHz–150 kHz, 80Mhz – 200 Mhz not scanned, limits differ
- RE102 to CISPR 22 - 10 kHz – 30 Mhz , 1 GHz – 18 Ghz not scanned , limits differ
- RS103 to 61000-4-3, 4-6 - 2 Mhz – 80 Mhz, 1 Ghz – 40 Ghz not scanned, limits differ

EU Terma Scanter Test Report – DANAK - Measurements of Radio Frequency Interference (Radiated & Conducted)

Statement: The above test report has been found to not contain evidence that the Terma Scanter demonstrates conformance to the requirements of MIL-STD-461F and would therefore, **not** have to be retested to the military standards.

RISK: Very High

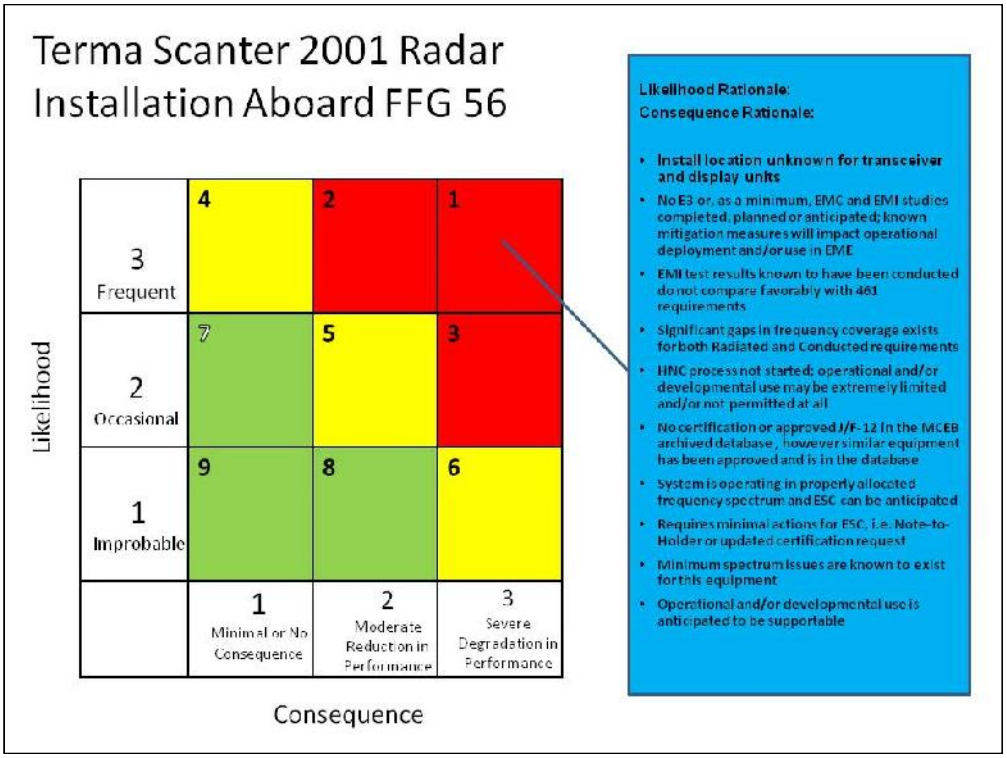
RECOMMENDATION: Acceptability of risk - NONE

EU Terma Scanter Test Report – DANAK - Measurements of RFI (Susceptibility) Immunity)

Statement: The above test report has been found to not contain evidence that the Terma Scanter demonstrates conformance to the requirements of MIL-STD-461F and would therefore, **not** have to be retested to the military standards.

RISK: High

RECOMMENDATION: Acceptability of Risk- NONE



E3 Engineering Assessment (courtesy NAVSEA)

Potential for EMI to surrounding below deck systems: The radar passed several European test standards. EN50081-1 for conducted emissions, EN50081-1 for radiated electric fields and EN61000-3-2 for AC Mains Harmonic current emissions. The provided measured data confirmed the conclusion that the radar transceiver units were within the stated limits. Testing was also conducted for immunity to below deck environments defined by the European commercial specifications. The tests did not conform to the maritime IEC 60945 limits that we have approved for the NVR. The tests performed were done with CISPR 22 Class B which is information technology equipment for home use. The JSC specification comparison report states that CISPR 22 is not acceptable for use in place of MIL-STD-461 RE 102 due to the mismatch in frequency coverage and the less stringent levels. A comparison of the CISPR 22 limits for conducted emissions to CE102 does show favorable results. The EN50081-1 limits were much more conservative than CE102 at least over the limited frequency range covered.

If it is X band then we would also have a concern about interference to any existing SPS73 onboard.

So the provided data is a mixed bag. The Scanter transceiver most likely will be compatible with the ship power system. The transceiver unit may cause interference to surrounding systems depending upon where these units are installed.

The provided data did not cover the radar PPI or display unit. The requirements for the display are provided in IEC 60945 and should be met if this unit will be placed in the bridge. At a minimum the display unit must be placed well away from the ships compass, and other critical navigation systems.

If the TERMA Scanter radar is installed then careful checks must be performed on all nearby systems to confirm proper operation prior to deployment. Without further tests in accordance with MIL-STD-461 or IEC 60945 I would be unable to characterize the risk of this temporary install. ***Therefore I consider this installation to be high risk for causing EMI and its operation must be conducted with care and limited to US&P coastal waters.***

Spectrum Certification: The NTIA Stage 4 certification was approved for the X band 25 kW unit. The area of operation was US&P (Coastal Port Regions)as the Coast Guard was the requesting activity. There were several caveats in the use of the radar as it was not fully compliant with all requirements. IT appears that use of the radar during deployment within US controlled water is permissible. Use outside of US&P controlled water would not be covered under this spectrum certificaiton. Other issues of potential for interference to existing surface navigation radar and SLQ-32 onboard the FFG still requires investigation.

VII. **MITIGATION OF UNACCEPTABLE RISK**

Mitigate Risk through Design and/or Retest:

This process comprises two options:

Retest the COTS equipment to determine compliance with EMI requirements, MIL-STD-461 or otherwise. This is technically a good approach as any subsequent required protection can be properly specified, and over-protection will be avoided. However, the disadvantage of this approach is the cost implications of the additional testing required.

Remedial re-design can be achieved by adding the appropriate protection 'barriers' to reduce the coupled RF fields or currents the equipment could be exposed to or could emit to below the levels it was originally required to meet. Many manufacturers now offer suitable RF shielded racks and enclosures for this purpose. These allow the /COTS equipment to be housed without modification such that line replacement is readily achieved. The gap analysis process provides the barrier performance specification required. Where a piece of modified COTS equipment becomes "modified-off-the-shelf" equipment marketed as a variant or new model, the resulting equipment needs to meet the EMC Directive with CE marking as a 'new apparatus' in its own right.

Once each risk has been identified and documented as in the previous sections, various options can be explored to reduce each risk to an acceptable level (Program Risk Chart). Some of the measures that may need to be explored are:

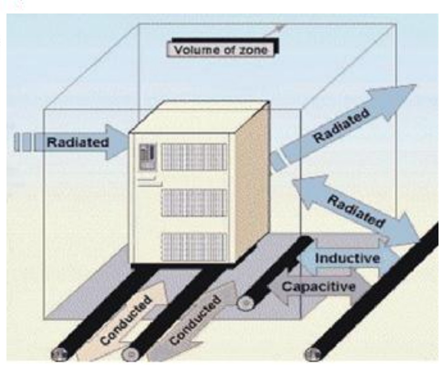
- **Installation**
- **Re-packaging**
- **Shielding or Filtering**
- **Additional Qualification**

EMC measures should equally extend to:

- decoupling the interference path between source and affected equipment/system;
- reduction of the level of emission at its source;
- increasing the immunity to the disturbance at the affected equipment/system.

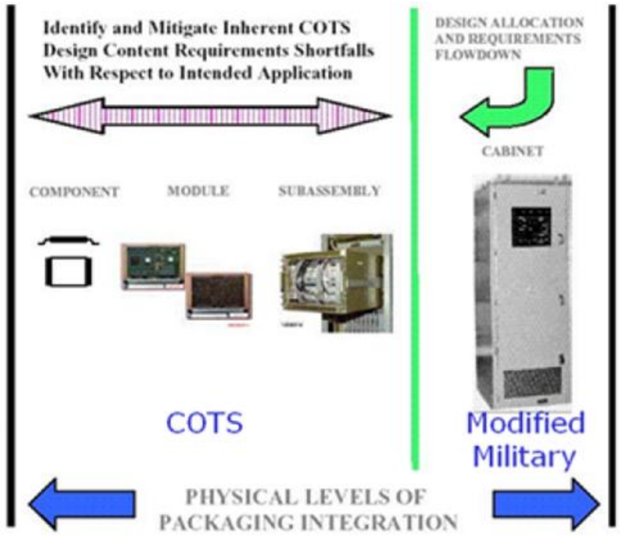
The following measures can be applied individually or in combination:

- screening;
- grounding;
- suitable cable routing, cable separation and cable selection;
- selection of suitable equipment mounting place;
- filtering;
- use of special components (for example overvoltage protectors);
- use of special devices (for example to separate different potentials);
- organizational measures (for example alternating operation of devices).



Mitigation Through Installation

- Compartment Separation
  - Graded Compartments
- Within Compartment
  - Shielded Rack
  - Spatial Separation (Zones)
  - Filtering
  - Cable Segregation
- Within Rack
  - Shield Zones
  - Filtering
- Appropriate Earthing, Bonding



Mitigation through Re-packaging

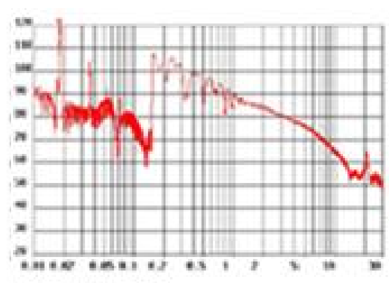
Mitigation Through Shielding or Filtering

- Conducted emissions can be dramatically reduced by using a multiple stage line filter.

- Radiated EMI may be eliminated or reduced by the use of shielded enclosures and shielding materials.
  - Act as a barrier to electromagnetic energy
  - Reduce radiated emissions and also improving susceptibility to electric and magnetic fields.

Mitigation Through Additional Qualification

- Target Testing to Main Threat/Vulnerability e.g.:
  - If operates near High power Radar – test at radar frequency and anticipated level.
- Physical Separation (if possible)
  - Golden Rule 'if equipment likely to interfere – separate'



- Use of compartment interference matrix
  - Identifies sources and victims
  - Determines extent of separation
  - Used to aid 3D CAD Layouts

EM design measures are often a compromise between the ideal and the practical implementation, all of which can introduce cost into the use of the COTS product either in price to produce, delays in implementation and/or verification testing.

In many cases, the cost of retesting can be dramatically reduced by performing a pre-scan across the electromagnetic spectrum in lieu of a complete scan, focusing on the areas of the spectrum that interfere with other spectrum dependent devices within the anticipated environment. The scan would reflect the actual impact of implementing the proposed change to the design at the exact frequencies that are of concern. The amount of test time will result in a much lower cost to verify the proposed mitigation.

Any kind of risk mitigation needs to be performed by personnel with relevant EMC competencies, especially if it is determined that a change to the product to reduce the risk level to an acceptable level is not verified by retesting of any type.

Mitigation Guidance Summary

- Evaluating the use of Commercial/industrial EMC standards have to strike a balance between cost saving and risk. Risk mitigation shall take precedence over cost savings in high risk situations or when there are highly sensitive intelligence or security concerns.
- Critical systems have to be specified and protected appropriately.
- Any kind of change to the design of the product, such as, adding gasket material or changing line filters should be followed by a minimum of a verification scan to verify and document the impact the change had on reducing the risk to a hopefully acceptable level.
- All risk mitigations need to be documented appropriately to ensure all the reasoning and actions to reduce the risk to an acceptable level are captured.

Appendix A – Commercial EMC Compliance Requirements

The following information is provided to understand the framework and complexity of the two main commercial EMC arenas (EU and U.S.) that test data in a report form or declaration to compare to our MIL-STD-461 requirements can be found. If test results/reports are obtained from the manufacturer, an effective gap analysis can be conducted and it can be determined whether reduction in the amount of testing can be reduced in testing COTS equipment for a military application, thus, a realized cost reduction.

FCC

The body responsible for regulation of EMC emissions in the USA is the Federal Communications Commission (FCC). The FCC has the authority to regulate EMC emissions from all equipment that emits electromagnetic energy on frequencies within the radio frequency spectrum. The intent is to prevent harmful interference to authorized radio communication services.

The two main regulations that deal with EMC are Part 15 (Radio Frequency Devices) and Part 18 (Industrial, Scientific and Medical Equipment (ISM)).

Part 15 covers low power unlicensed devices which use radio-frequency energy and may be intentional or unintentional radiators. Certain devices are exempted, including:

- Digital devices used exclusively as industrial, commercial or medical test equipment
- Digital devices used exclusively in an appliance, e.g. dishwasher, air conditioner, etc.
- Digital devices having a power consumption not exceeding 6 nW

Digital devices are classified into Class B devices, which are marketed for use in a residential environment, while Class A devices are marketed for use in a commercial, industrial or business environment.

Examples of Class B devices include, but are not limited to personal computers, calculators and similar electronic devices that are marketed for use by the general public.

Conducted and radiated emissions testing are required by Part 15, either to the limits stated in Part 15 or according to CISPR 22, with the following stipulations:

The limits CISPR 22 must be used in their entirety. You cannot mix results using CISPR 22 and Part 15.

Additional testing above 1GHz must be carried out for equipment with clock frequencies above 108MHz.

The test procedures must be those specified in Part 15 and ANSI C63.4, not those in CISPR 22.

Testing must be carried out using the same mains power supply as used in the USA, i.e. 120V, 60Hz.

Subpart C of Part 15 covers intentional radiators and gives details of permitted frequency ranges and field strengths.

When considering the purchase of unlicensed devices for use by the Federal Government, the Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook) needs to be referenced. Basically the Red Book mirrors the FCC topic of non-licensed devices, including Annex K. Annex K sets out the Federal Government regulations and technical specifications under which a low power intentional, unintentional or incidental radiator or device may be operated officially by a Federal Government Agency without an NTIA approved frequency assignment". The following sections of the Redbook are of major importance when considering use of unlicensed devices COTS equipment in military applications within the United States:

- ***7.8 Purchase and Use of Non-Licensed Devices*** Federal Government agencies may, without further authority from the Assistant Secretary, purchase"off-the-shelf" non-licensed devices that conform to the applicable edition of Part 15 of the Federal Communication Commission's (FCC) Rules and Regulations (47 CFR 15). Authorization statement from the NTIA
- ***7.9 Development and Use of Non-Licensed Devices*** Agencies may develop and operate devices that conform to the technical criteria in Annex K without further authority from the Assistant Secretary. This statement gives the agencies authority to develop and operated non-licensed devices without approval from NTIA (JF12's generated).
- ***10.3.7 Non-Licensed Devices*** Plans or proposals to operate non-licensed devices shall be submitted to the SPS for record. Therefore, information about the device must be submitted to the NTIA, either by 1494 or some other acceptable means.

It is important to remember DOD activities ***<u>will not use non-licensed devices</u>*** for critical, tactical or strategic command and control applications essential for:

- Mission success
- Protection of human life
- Protection of high value assets.

Part 18 covers equipment or appliances designed to generate and use locally RF energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunication.

Typical ISM applications are the production of physical, biological, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal and acceleration of charged particles.

Conducted and radiated emissions testing are required by Part 18 and the limits are provided within the text of the regulations.

The following procedures are spelled out within the regulations:

- **Declaration of Conformity**
- **Certification**
- **Verification**

<u>Declaration of Conformity</u>

Class B personal computers and their peripherals, and consumer ISM equipment (e.g. microwave ovens) are authorized by the Declaration of Conformity procedure or the Certification procedure.

The manufacturer must:

- Get the product tested at a laboratory which has been accredited by A2LA or NAVLAP for EMC testing.
- Prepare a technical file
- Mark the product and place the requirement FCC notices in the user manual
- Prepare and sign a Declaration of Conformity

<u>Certification</u>

Certification is an alternative route for those products requiring a Declaration of Conformity. Certain other products (e.g. scanning receiver, intentional radiators) **always require certification**.

The manufacturer must:

- Get the product tested at a laboratory which has been listed by the FCC.
- Submit the test report, together with a proposed FCC ID Number to the FCC
- If approval is granted, mark the product with the FCC ID number and compliance statement, and place the required FCC notices in the user manual.

<u>Verification</u>

Verification is required for products that Certification or Declaration of Conformity are not required.

The manufacturer must:

- Get the product tested
- Retain the verification records for possible review by the FCC
- Mark the product with a compliance statement, and place the required FCC notices in the user manual

<u>Documentation and Marking</u>

As can be seen above, the function of the COTS equipment and selection of process by the manufacturer will determine the appropriate marking and documentation required to be generated to support the conformance to the FCC requirements, especially if the product has the FCC ID number displayed on the product and the required FCC notices in the user manual.

If the COTS equipment manufacturer has successfully tested to the FCC EMC test requirements, they should be willing to give access to the associated test report the manufacturer has supplied you with their FCC ID, enter that ID into the appropriate field at the below location to obtain more information on the product at the FCC.

FCC ID Search: http://www.fcc.gov/oet/ea/fccid/

FCC ID numbers are displayed on devices and indicate that the device has received a grant of authorization from the FCC. Manufactures of devices that possess the potential to cause radio frequency interference to other devices are required to meet the FCC technical requirements which may include the granting of an FCC ID number. The rules, located in 47 CFR 2.803 and 47 CFR 2.1204, require that most devices be authorized before they can legally be imported or sold in the USA. These rules also require that labels with the information prescribed by the FCC be affixed or accompany the device. Not all devices approved for sale and operation by the FCC rules require an FCC number however. Refer to the FCC web site (http://www.fcc.gov) for more information.

B. European

The European Union issues directives that must be adhered to by member countries. There are many directives that cover different classifications of equipment in the European Union, such as safety, EMC, and medical. At present, there are two main directives in the EU dealing with EMC:

2004/0108/EC EMC Directive

1999/5/EC Radio and Telecommunications Terminal Equipment (R&TTE)

As can be expected, the EMC Directive exempts R&TTE equipment from being compliant to the requirements of the EMC Directive.. After April 7, 2001, all radio and telecommunications terminal equipment must be in full accordance with the new provisions of the R&TTE Directive. Both directives specify general requirements that apparatus be constructed such that:

“The electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended” and

“The apparatus has an adequate level of intrinsic immunity of electromagnetic disturbances to enable it to operate as intended.”

Both Directives also states:

- The manufacturer shall perform an electromagnetic compatibility assessment of the apparatus.

- The electromagnetic compatibility assessment shall take into account all normal intended operating conditions.
- The compliance of apparatus with all relevant essential requirements shall be attested by an **EU Declaration of Conformity** issued by the manufacturer or his authorized representative in the Community. This declaration should be available upon request and must list the specifications used to demonstrate compliance.
- The manufacturer or supplier must maintain **'Technical Documentation**' containing an EMC assessment which contains a test report and design information.
- Products sold in Europe must contain the **CE mark** as an indication of compliance.

EU Declaration of Conformity (DoC)

The EMC standards in the European Union are of several different types: product, product family, generic and basic. Each performs a specific purpose of grouping or classification.

Product and product family standards define the requirements and test methods for a small range of products. Product standards are produced by product committees who determine what requirements must be applied for a particular product or product family to meet the intent of the intended directive.

Generic standards define the requirements and test methods for those product types that are not covered by the more specific product and product family standards. Generic standards are based on types of environment rather than product categories. The generic standards are available to be used when a “product” standard which addresses the particular item does not exist. The generic standards list the individual test standards (generally, IEC and CISPR documents) that are applicable and the limits that apply. They will generally refer to the **basic standards** set out test methods or provide guidance and background information. They may contain recommendations but do not set absolute requirements. Consequently, basic standards do not of themselves provide a presumption of conformity. Rather they provide standardized test methods that can be referenced from the other standard types.

The DoC may be with the equipment documentation, on the manufacturer's website, or supplied on request. It is usually a 1 sheet declaration that contains a list of all the EU directives and optionally all the standards with which the product is in conformance. At a minimum the directives must be listed. As for the standards, the DoC might not list the individual standards.

For example, if the Declaration of Conformity lists ONLY the EMC Directive, then, a request to the manufacturer for a list of the actual standards they are in conformance and test reports reflecting conformance EU standards to be compared to MIL-STD performance test expectations for our evaluation.

The CE Mark

The CE marking affixed to products is a declaration by the person responsible that the product conforms to all applicable Community provisions and the appropriate conformity assessment procedures have been completed. You will find the CE mark affixed to the product, its instruction manual or to its packaging.

The CE mark is not intended to be a mark of quality rather it is intended to indicate to the authorities responsible for enforcing the Directives that the product's manufacturer claims compliance with the directives which apply to the product. It symbolizes the conformity of the product with the applicable Community requirements imposed on the manufacturer.

Technical Documentation

The technical documentation must enable the conformity of the apparatus with the essential requirements to be assessed. It must cover the design and manufacture of the apparatus, in particular:

- A general description of the apparatus
- Evidence of compliance with the harmonized standards, if any, applied in full or in part

Where the manufacturer has not applied harmonized standards, or has applied them only in part, a description and explanation of the steps taken to meet the essential requirements of the directive, including a description of the electromagnetic compatibility assessment, results of design calculations made, examinations carried out, test reports, etc.

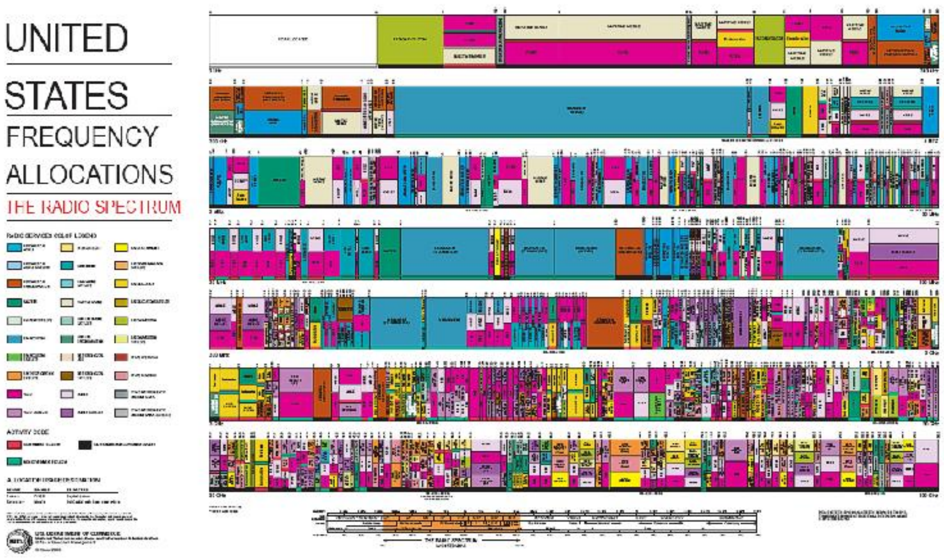
If a manufacturer has labeled his product with a CE mark, he must have created a Declaration of Conformity and a technical file has been created. If the COTS equipment is CE marked, then it is appropriate to contact the marketing or sales organization /representative for the manufacturer a copy of the Declaration of Conformity and access to the technical file. Access to the technical data might require contacting the engineering department for access. EU member countries will not import products within their borders without a Declaration of Conformity.

Without the technical file contents being supplied, the applicability of the COTS equipment to the military application becomes very difficult. A gap analysis cannot be accomplished, testing reduced without high risk, and an ultimate reduction in testing cost. It is imperative that whatever testing has been done to the COTS equipment must be expressed at the same level as any MIL Standard requirement.

Appendix B – Spectrum Certification Process

<u>Global Spectrum Management Organizations</u>

The International Telecommunications Union (ITU) establishes the frequency regulations worldwide. The ITU has treaty status; more than 170 nations participate, including the US. Within each country's borders, they can deviate from the international standards as long as it doesn't impact any other nation. Deviations in a valid case for safety must be well documented and ideally approved prior to radiation of the system. The U.S. is one of the biggest "deviators" from these regulations in the world. The most "exceptions" to the rules can be found within our country.



Within the U.S., there are two groups that govern the spectrum: the Federal Communications Commission (FCC) for commercial systems and the National Telecommunications and Information Administration (NTIA) for all government systems (including DOD). Because the U.S. has so many spectrum-using high-technology devices, the FCC and NTIA have agreed upon three classes of spectrum owners: primary, secondary, and "FCC Part 15" devices. Part 15 devices include low power items such as cordless telephones, wireless local area networks (WLANS), garage door openers, radio frequency identification (RFID) tags, radio controlled cars, computer parts, etc. ***Part 15 devices have no legal status and must endure any interference that they receive and must not cause any interference to any legally authorized user of the spectrum.***

DD Form 1494

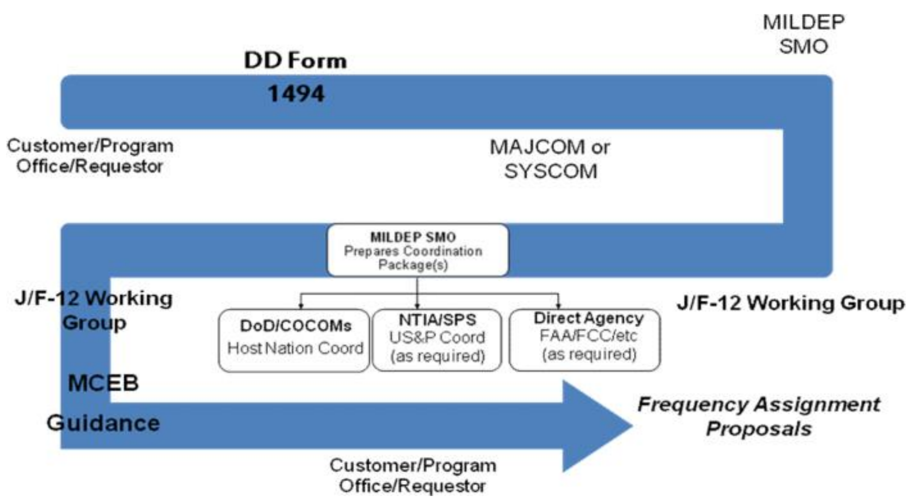
The civilian spectrum is, generally, not authorized for military use. It cannot be assumed that all COTS will be allowed to operate in a military environment. Much depends upon the technical characteristic of the transmitter and its spurious and harmonic emissions. For receivers, the out-of-band rejection requirements are of concern. Therefore, S-D COTS equipment cannot be procured without obtaining a certification of spectrum support, including the required national and host nation coordination to operate

DD FORM 1494

The cornerstone of spectrum certification is the DD Form 1494, titled “Request for Equipment Frequency Allocation”. It is the primary vehicle for requesting the use of spectrum in the U.S. and throughout the world. The form itself and instructions can be found at https://acc.dau.mil/spectrum/. The content of the form includes the proposed technical characteristics of the overall system, transmitter, receiver, and antenna.

The spectrum certification process starts with a Customer or Program Office submitting the required DD Form 1494 through the chain of command to a MAJCOM (Major Command), or SYSCOM (Systems Command) or HQ activity responsible for SM in their Service. The DD1494 is reviewed for sufficient data and accuracy throughout and once completed, is submitted to the MILDEP spectrum management office (SMO) for action. The data in the DD Form 1494 is required for EMC determination and supports authorization agencies in their analysis of equipment design.

The MILDEP SMO also reviews the DD Form 1494 for sufficient data, data accuracy, and begins the compliance checking with applicable standards, regulations and guidelines. Coordination packages are prepared and the DD1494 is then submitted to the J-12 Permanent Working Group (PWG), where the DD Form 1494 changes to a J-12 paper. The MILDEP SMEs, JSC, & NSA reps of J-12 working group review the data for accuracy, sufficiency, and potential conflicts with existing systems. If approved, the J-12 Steering Member signs the guidance package which is then distributed by the JSC through channels to the submitting MAJCOM, SYSCOM or MILDEP SMO. The submitter then initiates frequency assignment proposals for operational use based on MCEB guidance.



The As noted in the figure, the DD form 1494 is also the vehicle for implementing Host Nation Coordination (HNC) and ascertaining frequency supportability within the territories of foreign nations. In such situations, the use of the spectrum for U.S. operations is by permission of the Host Government and is formalized in an agreement between the U.S. and the Host Government. Each host nation has the sovereign right to permit or deny the US military access to the spectrum within its borders. To ensure EMC, the Host Government, in most cases requires the U.S. to supply data concerning the equipment characteristics from a spectrum usage standpoint. The data required in most of these situations is the same data elements as in the DD Form1494 even if the U.S. uses COTS equipment. ***There are no exceptions for commercial off-the-shelf (COTS), non-developmental item (NDI), receive-only, or Electronic Warfare (EW) systems when the equipment, system or subsystem is to be operated outside the United States by the US DOD***.

Not all non-licensed devices operating within the US&P require a DD Form 1494 to be filed and may be operated officially without a NTIA approved frequency assignment; however, DOD requires a frequency assignment registered in the FRRS. These devices include, but are not limited to: wireless local area networks, wireless barcode readers, bio-medical telemetry, and cordless telephones. Check with your service FMO for guidance on your specific application.

For more information refer to:

Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook)
http://www.ntia.doc.gov/osmhome/redbook/redbook.html
Chapter 8 Procedures and Principles for the Assignment and Coordination of Frequencies
ANNEX K Technical Standards for Federal "Non-Licensed" Devices

Annex K of the NTIA manual sets out the Federal Government regulations and technical specifications under which a low power intentional, unintentional or incidental radiator or device may be operated officially by a Federal Government Agency without an NTIA approved frequency assignment. Non-government operations of these radiators, called non-licensed devices or Part 15 devices, are regulated by the Federal Communications Commission (FCC) Code of Federal Government Regulations, Title 47, Part 15. FCC regulations and standards do not apply to the Federal Government although many low power devices are operated by the Agencies without an NTIA approved frequency assignment. The NTIA thus provides the regulations and standards in this Annex for regulating Federal Government official operations involving low power radiators as non-licensed devices. The regulations and standards in this Annex are a subset of the FCC Part 15 regulations.

<u>Spectral Adequacy Decision Process</u>. (From DOD Manual 3222.3, Draft (as of May 2010))

The overall decision process that should be used to evaluate the spectral adequacy of any COTS for an intended military application is illustrated in Figure 1.

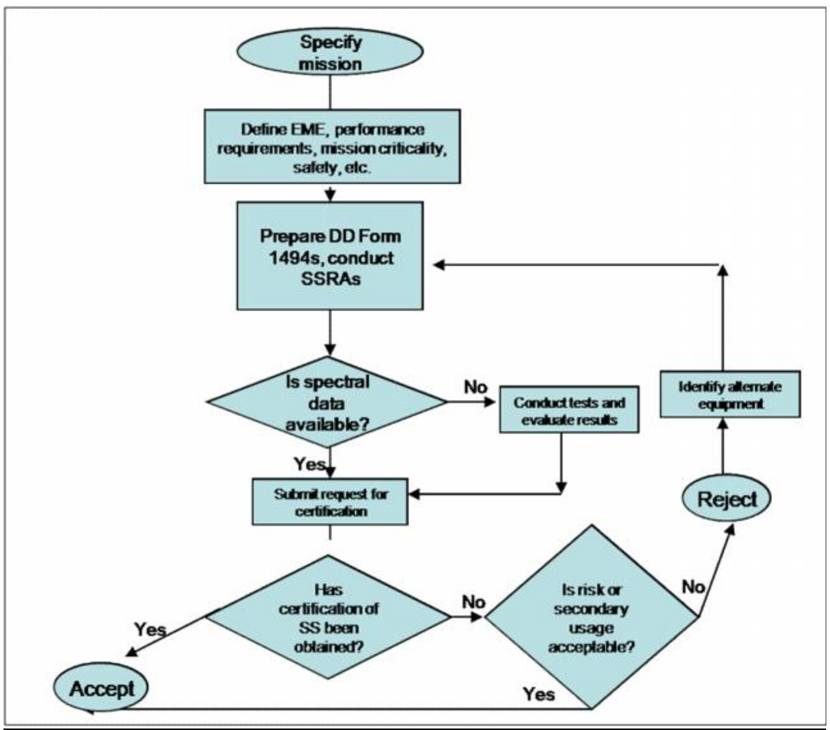


Figure 4- Flowchart for Evaluating Spectrum Supportability of COTS

1. <u>Determining Spectral Requirements</u>. When determining spectral requirements necessary to fulfill the mission the following should be identified:

a. Is the performance of the COTS safety or mission critical?
b. Frequency range of operation
c. Required throughput
d. Justification for bandwidth optimization in the proposed architecture
e. Required bandwidth based on recommended technology
f. Power output
g. Antenna gain and characteristics with proposed technology and rationale including cost impact
h. Area of operation (e.g., CONUS, outside CONUS (OCONUS), etc.)
i. Application: Fixed or Mobile
j. Host platform (e.g., dismounted soldier, airborne, etc.)
k. How mission requirements will be met while complying with SM regulations
l. The plans for obtaining certification in intended HNs

2. Spectral Data. Next, the availability of spectral data must be determined, whether the data describes the EM characteristics of the COTS, and how well those characteristics meet anticipated needs. As indicated earlier, COTS is generally not designed to operate in the harsh military EME and, in many instances, lacks sufficient emission control or susceptibility protection such that severe EMI problems can result. PMs must request the manufacturers of COTS to provide the requisite technical characteristics and spectral data needed to complete the process. If the data does not exist, the PM must program for and conduct the necessary tests to obtain the data. The data is required for the following:
   (a) The potential for EMI increases when DOD employs COTS since most COTS are not designed or tested for operation in the extremely dense, high power EME found during military operations. Conversely, the resolution of such problems is more difficult when this data is not available for use in developing potential fixes.
   (b) Site planning for the installation of COTS systems in DOD platforms or land facilities, while maintaining mutual compatibility between systems, is difficult, if not impossible to do in the absence of specific, spectrum performance data.
   (c) COTS with unknown, out-of-band emission characteristics can cause severe EMI to critical systems in the environment, requiring costly corrective action programs and probably reducing operational effectiveness.
   (d) Spectrum planners, who develop frequency plans for DOD missions, are responsible for assigning frequencies to preclude EMI among the multitude of emitters and receivers that will operate in the battle space or in training exercises. Non-certified emitters and receivers constitute unknown quantities that present a hazard to spectrum planning and overall mission success, regardless of their operational frequencies.

Certification of COTS

When contracting for the acquisition of S-D COTS, particularly those that utilize civilian frequencies, it is essential that the ESC process described previously be followed. Submissions of Stage 3 and/or Stage 4 DD Form 1494s are required for COTS planned for use by the military, including FCC Part 15 devices. Approval is contingent upon compliance with the provisions of NTIA Manual and is applicable only for use in the US&P on a non-interference basis. Approval for use outside the US&P is difficult to obtain and is based on formal HN coordination and approval via the COCOMs.

(1) DOD is afforded access to, and shares, the spectrum with other Federal Agencies, local Governments and private Industry. Consequently, DOD must demonstrate critical needs to maintain specific portions of the spectrum for exclusive use. This is truer now more than ever before considering the wide use of wireless technologies in the market-place. .

(2) Government requirements for use of the spectrum in exclusive non-Government bands can be accommodated either by becoming a user of a commercial service, such as cellular telephone, or by obtaining a secondary allocation. When using a commercial service, a Government user may buy or lease COTS equipment that has been “Type-Accepted” in accordance with FCC rules.

(3) Secondary allocations can be even more of a problem for the Government user who, in this case, is afforded no protection at all from EMI. Furthermore, regulatory policy stipulates that primary allocation operations will experience no EMI from secondary users. Consequently, operational EMI can be expected in the absence of appropriate spectral considerations during acquisition.

(4) Relocation of COTS to new frequency bands is difficult, costly, and may cause interactions with other equipment. In addition to the increased likelihood of operational EMI because of overcrowding in the remaining spectrum, equipment redesign, additional testing, re-certification for spectrum use, and training all may be necessary.

Risk Assessments

When evaluating the risks associated with the use of COTS, the following should be considered:

1. Are there possible interactions with other S-D systems in its intended operational environment?
2. Will the proposed utilization of spectrum demonstrate the service prioritization and spectrum utilization prioritization in the battlefield environment with other existing and proposed systems?
3. Is the best available technology being used for its spectrum requirement?
4. Has the proposed COTS considered the spectrum sharing/utilization with other deployed systems to achieve its mission requirement?
5. Will the overall system or platform mission requirements be met if the proposed COTS

does not comply with SM regulations?

6. What is the likelihood of obtaining certification and HNA in intended operational and training areas?
7. Is relocation to another frequency band feasible?
8. Are there other options available to satisfy the required performance (COTS, NDI, or GOTS)?

If after evaluation of the COTS, it is determined that it would probably not be certified, then it is the responsibility of the procuring activity to implement to select other equipment (e.g. COTS, NDI, or GOTS) with adequate characteristics.

If COTS equipment is to be used in dense electromagnetic environments such as found aboard a ship or on an airplane, either as part of commercially provided service or on secondary or NIB allocation status, the potential for mutual interference is increased. Under such conditions, the harmonic and spurious emissions of the COTS transmitters as well as any emissions generated by the COTS receivers can be sources of interference. Further, where the DOD places reliance on the commercially provided services, on secondary allocations or on use of NIB, the receiver spurious response characteristics of COTS equipment can be involved in interference from other equipment. Thus, where COTS equipment is used by the DOD in non-Government exclusive bands where dense electromagnetic environments are involved, the equipment characteristics concerning interference potential are required.

Use of COTS equipment with a secondary allocation or a footnoted NIB affords no protection to the Government user and requires that primary allocation operations will receive no interference from the secondary or NIB Government user.

In summary DD1494 data should be obtained on all COTS equipment, unless there is absolute assurance that a particular equipment type will be used only in the US&P in normal non-Government environments. If such assurance is given, FCC type acceptance and manufacturers specification data should be provided.

Appendix C – Risk Assessment Analysis Template

Note: Based loosely on Navy A – O Message format (outline at end)

INTERVIEW/RESEARCH TEMPLATE (DRAFT)

System Specifications/Risk Assessment Information

A. Identification of E3 RA / title
B. Category of System (Dependent on Final Category Definitions!)
C. Operational impact – summary of RA?

Questions/Info Desired

D. Manufacturer's name and P/N for total system being evaluated.
E. EME of system subsystems Entire system to be located in same environment (bridge/below deck etc.)?
F. Power requirements DC voltage/current; AC voltage/current/frequency/phases If Both AC/DC,? Which one is being considered?

1. Determine the Electromagnetic Environment (EME)

a. Installation location (Ship/Land/Air)
b. List ALL environments in which the equipment will be operated
c. Intentional/unintentional emitter
d. Transportation/storage/repair requirements
e. HERO/HEMP/HERF/EMP/ESD requirements
f. Categorization

Questions/Info Desired

- Research Effort: Google system name/nomenclature to get additional information, spec sheets, etc.
- Interview originator, determine mission profile of system, discuss mission criticality, platform/location information (including antennas/transmitters in close proximity), what test data is available
- Need any program, requirements, CONOPs, etc. documentation that might help with information on use of COTS item, categorization, criticality, etc.
- Need extensive information on installation and intended use
    - Any known previous use experience by another service or organization?
    - Is it mission or platform critical? Why?
- Desire life cycle transportation, storage and maintenance plans as pertains to changing EME
- What can they tell us about other EM related requirements such as HERO/HEMP/HERF/EMP/ESD

2. Spectrum Certification

Questions/Info Desired

- Is there a DD 1494 exist? Has a DD Form 1494 been filed? If so, what is the 1494 Status (what stage approved)? Can we get a copy? If not, has the process been started?
- Is there Local Frequency Office frequency approval (at the intended operational location)?
- Host Nation requirements and status?

3. Evaluate COTS EM Performance and Conduct Gap Analysis

a. Identify Commercial EMC standards/Obtain & Analyze data
    i. FCC, EU Declaration of Conformity
    ii. EMI/ EMC Test Report Data
b. List MIL-STD-461F Required/Desired Tests
c. Perform Gap Analysis for Each Test
d. Assign Risk Severity to Gaps

Questions/Info Desired

- Has the equipment/component been qualified for a CE Mark or FCC Certification?
    - If Yes, state which one
    - If FCC certified, verify in data base.
    - If so, is there any known EMI requirements or test data?
    - Can they help get it for the E3 risk assessment?
- If CE Mark, can we get the Declaration of Conformity?
    - Need listing of EMI standards met
    - Want Technical File, test results/data EMC standards including sub sets of EMC standards that have been applied.
    - Overview of any EMC analysis undertaken together with conclusions.
    - Details of the Competent Body/EMC Specialist that has endorsed the TCF
- Indicate which categories of EMC compliance are applicable to the equipment
    - European EMC product Specific/Family Standards
    - European EMC generic Standards for Residential, Commercial and Light Industrial Environments.
    - European EMC generic Standards for Industrial Environments.
- Defence Standards (MIL-STD-461, DEF Stan 59-411, etc)
    - Ship below decks environment
    - Ship above decks environment.
    - Other Environments (Specify)

- Has there been any EMI or integration testing done by the program office? Is any planned?
    - Is so, what are the EMI test requirements? Is there a test plan we can review?

4. Risk Analysis

a) Criticality vs. EME Zones
b) The Risk Cube
c) Threat Severity Table
d) Mishap Probability Table
e) Impact to Existing Systems – will have to define
f) Interoperability Impact – will have to define

5. Mitigation Plan

a) Any documentation requirements (for redesign or corrective action efforts)

Note: Based on A – O Formatted Navy Message (outline below). Green indicates applicable to Risk Assessment template, Red indicates not applicable.

A- Identification of change / title
B- Type of change (hardware, software, or firmware) – N/A for E3 RA
C- Purpose of change – NA for E3 RA
D- Operational impact – Specifically address which criteria the change meets: Significantly improves warfighting capability, correct critical operational deficiency or improves safety - Summary of RA?
E- Prerequisite requirements
F- Testing accomplished for approval / certification
G- Schedule that has been coordinated with ships's force – NA for E3 RA
H- Integrated logistics support requirements– NA for E3 RA
I- Training requirements – include assessment of current NTSP and/or recommend NTSP changes– NA for E3 RA
J- Impact to existing systems
K- Risk assessment
L- Contingency (options / fall back) – Mitigation Plan
M- Documentation requirements – Gap Analysis (3a), Mitigation Plan
N- Interoperability impact– Mitigation Plan
O- Install point of contact and phone number– NA for E3 RA

Appendix D – Case Studies - Pending

Appendix E - References

1. Defence Standard 59-411, Electromagnetic Compatibility, Part 1 Management and Planning
2. Engineering Practice Study (EPS) 0178, March 2, 2001, *Results Of Detailed Comparisons of Individual EMC Requirements and Test Procedures Delineated in Major National and International Commercial Standards With Military Standard MIL-STD-461E*
3. **3.** https://acc.dau.mil/CommunityBrowser.aspx?id=128255&lang=en-US
4. EMCUK2007, Gap Analysis between Defence and Commercial Standards, Peter Dorey, TÜV Product Service
5. EMCUK2008 Gap Analysis of Military Standards for CE Marking Peter Dorey, TÜV Product Service
6. Practical paper, Risk Analysis by the Use of Commercial Equipment in a Military Environment, Henk A. Klok, Royal Netherlands Navy
7. Risk Management Guide for DOD Acquisition, Sixth Edition, Version 1.0, August, 2006, Department of Defense Defense Acquisition University
8. Naval Systems Engineering Guide, October 2004
9. Guide to EMC Directive Conformity of Equipment Designed for Military Purposes, CLC/FprTR 50538, Draft, June 2010
10. Managing & Planning the EMC of MOTS and COTS Used Within MOD Systems & Platforms, Pete Dorey, TÜV Product Service Ltd., Article in Interference Technology Magazine, 05/16/08
11. AECTP-500 Electromagnetic Environmental Effects Test and Verification, Edition 3, February 2009
12. SD-2, DoD Acquisitions Buying Commercial Items and Non-developmental Items, Defense Standardization Program Office, January 2010
13. U.S. Department of Commerce
    Manual of Regulations and Procedures for Federal Radio Frequency Management, January 2008 Edition, January 2009 Revision
    ANNEX K, 1/2008, Technical Standards for Federal "Non-Licensed" Devices

14. Defense Acquisition Guidebook

https://akss.dau.mil/dag/

15. Defense Acquisition University, Commercial Off-the-Shelf (COTS) Acquisition for Program Managers (CLM 025) https://learn.dau.mil/html/clc/Clc.jsp

16. DOD Directive 5000.01,“The Defense Acquisition System” http://www.dtic.mil/whs/directives/corres/pdf/500001p.pdf

17. DOD Instruction 5000.02,“Operation of the Defense Acquisition System” http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf

18. DOD Specifications and Standards (ASSIST) http://assist.daps.dla.mil/online/start/

19. GR-1089-CORE, Electromagnetic Compatibility and Electrical Safety - Generic Criteria For Network Telecommunication Equipment

20. MIL-HDBK-237B:1997—Electromagnetic environmental effects on platforms, systems, and equipment.

21. MIL-STD-461F:2007—Requirements for the control of electromagnetic interference, characteristics of subsystems and equipment.

22. MIL-STD-464B:2002—Electromagnetic environmental effects requirements for systems

23. MIL-STD-882D, Standard Practice for System Safety, 10 February 2000

Appendix F – Acronyms

AECTP	Allied Environmental Conditions Testing Publication
AESOP	Afloat Electromagnetic Spectrum Operations Program
ANSI	American National Standards Institute
AS	Acquisition Strategy
ASD(NII)	Assistant Secretary of Defense for Networks and Information Integration
CCEB	Combined Communications-Electronics Board
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CENELEC	European Committee for Electrotechnical Standardization
CFR	Code of Federal Regulations
COTS	Commercial-Off-The-Shelf
CI	Commercial Items
CIO	Chief Information Officer
CISPR	International Special Committee on Radio Interference
CJCSI	Chairman of Joint Chiefs of Staff Instruction
CJCSM	Chairman of Joint Chiefs of Staff Manual
CNO	Chief of Naval Operations
COCOM	Combat Command
CPD	Capability Production Document
CPM	Communications Planning Module
CRD	Capstone Requirements Document
CTS	Commercial Telecommunications Services
CW	Continuous Wave
C2IP	Command and Control Initiative Program
C4I	Command, Control, Communications, Computers, and Intelligence
C4ISR	C4I, Surveillance, and Reconnaissance
DAS	Defense Acquisition System
DDT&E	Director, Developmental Test and Evaluation
DID	Data Item Description
DISA	Defense Information Systems Agency
DoC	Declaration of Conformity
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DODISS	Department of Defense Index of Specifications and Standards
DOT&E	Director, Operational Test and Evaluation
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities
DSO	Defense Spectrum Office
DT&E	Developmental Test and Evaluation
ECM	Electronic Countermeasures
EED	Electro-Explosive Device
E3	Electromagnetic environmental effects
EID	Electrically Initiated Device
EM	Electromagnetic
EMC	Electromagnetic compatibility
EMCS	Electromagnetic compatibility standardization

EMCAP	Electromagnetic Compatibility Analysis Program
EME	Electromagnetic environment
EM-TARTT	Electromagnetic - Test And Requirements Tailoring Tool
EMI	Electromagnetic interference
EMP	Electromagnetic Pulse
EMR	Electromagnetic Radiation
EMV	Electromagnetic Vulnerability
EN	European norm
EP	Electronic Protection
EPS	Engineering Practice Study
ESC	Equipment Spectrum Certification
ESD	Electrostatic Discharge
ESGPWG	Equipment Spectrum Guidance Permanent Working Group`
EU	European Union
EUT	Equipment Under Test
EW	Electronic Warfare
E3	Electromagnetic Environmental Effects
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FMO	Frequency Management Office
FOC	Final Operating Capability
FoS	Family of Systems
FRP	Full-Rate Production
GATE	Graphical Analysis Tool for EMEs
GFE	Government Furnished Equipment
HEMP	High Altitude Electromagnetic Pulse
HERF	Hazards of EM radiation to Fuels
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of EM Radiation to Personnel
HIRF	High Intensity Radio Frequency
HoD	Heads Of Delegation
HNA	Host Nation Approval
ICD	Initial Capabilities Document
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMI	Intermodulation Interference
IOC	Initial Operating Capability
IPT	Integrated Product Team
IRAC	Interdepartment Radio Advisory Committee
ISM	Industrial, Scientific, Medical
ISO	International Organization for Standardization
ISP	Information Support Plan
ISR	Intelligence, Surveillance, and Reconnaissance
IT	Information Technology
ITE	Information Technology Equipment
ITR	Initial Technical Review
ITS	Information Technology System
ITU	International Telecommunications Union
JCIDS	Joint Capabilities Integration and Development System
JCS	Joint Chiefs of Staff
JEET	Joint E3 Evaluation Tool

JFP	Joint Frequency Panel
JOERAD	JSC Ordnance E3 Risk Assessment Database
JROC	Joint Requirements Oversight Council
JSC	Joint Spectrum Center
JTIDS	Joint Tactical Information Distribution System
KPP	Key Performance Parameter
LFT&E	Live-Fire Test and Evaluation
LRIP	Low-Rate Initial Production
LISN	Line Impedance Stabilization Network
M&S	Modeling and Simulation
MAE	Maximum Allowable Environment
MARCORSYSCOM	Marine Corps Systems Command
MATDEV	MATerial DEVeloper
MCEB	Military Communications Electronic Board
MDA	Milestone Decision Authority
MIDLANT	AFC Mid-Atlantic Area Frequency Coordinator
MIL-HDBK	MILitary HanDBooK
MIL-STD	MILitary STandarD
MNS	Mission Need Statement
MOE	Measures of Effectiveness
MOP	Measures of Performance
MOTS	Military-Off-The-Shelf
MS	Milestone
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NERF	Naval Electromagnetic Radiation Facility
NMCSC	Navy and Marine Corps Spectrum Center
NAVSEA	NAVal SEA Systems Command
NAWCAD	Naval Air Warfare Center, Aircraft Division
NDI	Non-Developmental Items
NR-KPP	Net-Ready Key Performance Parameter
NRL	Naval Research Laboratory
NSA	National Security Agency
NSS	National Security Systems
NSWCDD	Naval Surface Warfare Center, Dahlgren Division
NTIA	National Telecommunications and Information Administration
NUWC NPT	Naval Undersea Warfare Center Newport
OATS	Open Area Test Site
OIPT	Overarching Integrated Product Team
OMB	Office of Management and Budget
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
OTA	Operational Test Agency
OTRR	Operational Test Readiness Review
PCR	Physical Configuration Review
PDR	Preliminary Design Review
PEL	Permissible Exposure Levels
PM	Program Manager
PRIMES	Preflight Integration of Munitions and Electronic Systems
P-Static	Precipitation Static

RADHAZ	Radiation Hazards
RCS	Radar Cross Section
RF	Radio Frequency
RFID	Radio-Frequency Identification
RR	Readiness Review
RTCA	Radio Technical Commission for Aeronautics
RTTC	Redstone Technical Test Center
SAE	Society of Automotive Engineers
SCS DMR	Spectrum Certification System Data Maintenance and Retrieval
S-D	Spectrum Dependent
SDD	System Development and Demonstration
SE	System Engineering
SFR	System Functional Review
SM	Spectrum Management
SME	Spectrum Management Engineer
SoS	System of Systems
SOW	Statement of Work
SPAWAR	Space and Naval Warfare Systems Command
SPS	Spectrum Planning Subcommittee
SRR	System Requirements Review
SS	Spectrum Supportability
SSC	SPAWAR Systems Center
STANAG	NATO Standardization Agreement
SVAD	Survivability, Vulnerability, and Assessment Directorate
SVR/PRR	System Verification Review/Production Readiness Review
T&E	Test and Evaluation
TACOM	Tank Automotive Command
TC	Technical Committee
TDS	Technology Development Study
TEMP	Test and Evaluation Master Plan
TEMPEST	Standard of shielding for wires/computers used by the US & other governments
TOA	Table of Allocations
TRR	Test Readiness Review
TTPs	Tactics, Techniques, and Procedures
UEM	Unified Electromagnetic Design
UK	United Kingdom (Britain)
UPS	Uninterruptible Power Supplies
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USMC	United States Marine Corps
V/m	Volts per Meter
WIPT	Working Level Integrated Product Team
WLAN	Wireless Local Area Network
WRC	World Radio Conference
WSMR	White Sands Missile Range

Appendix G – Glossary of Terms

Above deck
An area on ships which is not considered to be "below deck" as defined herein.

Below deck
An area on ships which is surrounded by a metallic structure, or an area which provides significant attenuation to electromagnetic radiation, such as the metal hull or superstructure of a surface ship, the pressure hull of a submarine and the screened rooms in non-metallic ships.

Electromagnetic Environment (EME)
EME is the resulting product of the power and time distribution, in various frequency ranges, of the radiated or conducted electromagnetic emission levels that may be encountered by a military force, system, or platform when performing its assigned mission in its intended operational environment.

External installation
An equipment location on a platform which is exposed to the external electromagnetic environment, such as an aircraft cockpit which does not use electrically conductive treatments on the canopy or windscreen.

Equipment Spectrum Certification (ESC)
ESC is the statement(s) of adequacy received from authorities of sovereign nations after their review of the technical characteristics of a spectrum-dependent equipment or system regarding compliance with their national spectrum management policy, allocations, regulations, and technical standards. Equipment Spectrum Certification is alternately called "spectrum certification."

Electromagnetic Environmental Effects (E3)
E3 is the impact of the EME upon the operational capability of military forces, equipment, systems, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility (EMC); electromagnetic interference (EMI); electromagnetic vulnerability (EMV); electromagnetic pulse (EMP); electrostatic discharge (ESD); hazards of electromagnetic radiation to personnel (HERP), ordnance (HERO), and volatile materials such as fuel (HERF); and natural phenomena effects of lightning and precipitation static (p-static). (JCS Pub 1-02).

Intentional radiator
A device that intentionally generates and emits radio frequency energy by radiation or induction.

Internal installation
An equipment location on a platform which is totally inside an electrically conductive structure, such as a typical avionics bay in an aluminum skin aircraft.

Non-developmental item (NDI)
Non-developmental item is a broad, generic term that covers material available from a wide variety of sources with little or no development effort required by the Government.

Safety critical
A category of subsystems and equipment whose degraded performance could result in loss of life or loss of vehicle or platform.

Spectrum Management (SM)
SM is the planning, coordinating, and managing Joint use of the electromagnetic spectrum through operational, engineering, and administrative procedures, with the objective of enabling electronic systems to perform their functions in the intended EME without causing or suffering unacceptable EMI. (JCS Pub 1-02)

Spectrum Supportability (SS)
SS is the assurance that the necessary frequencies and bandwidth are available to military systems in order to maintain effective interoperability in the operational EME. The assessment of an equipment or system as having "spectrum supportability is based upon, as a minimum, receipt of equipment spectrum certification (ESC), reasonable assurance of the availability of sufficient frequencies for operation, Host Nation Approval (HNA), and consideration of EMC.

Topside areas
All shipboard areas continuously exposed to the external electromagnetic environment, such as the main deck and above, catwalks, and those exposed portions of gallery decks.

Unintentional Radiator
A device that intentionally generates radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.

Appendix H - Tools

A. EM-TARTT Electromagnetic Test & Requirements Tailoring Tool

To assist with Naval Surface Ship's E3 Tailoring, NAVSEA has developed an informal custom software package to calculate tailored MIL-STD-461F and MIL-STD-464A EMV test requirements. Both these standards allow tailoring of the limits and test criteria, but do not provide the guidance for an inexperienced Program Manager untrained in EMC to tailor the requirements based on the operational environment and the risk of EMI. The Navy has been discussing methodologies that would provide the acquisition community and program managers the necessary guidance to tailor EMC requirements consistent with EMI risks. The contracting agency (or prime contractor), though, must identify when a requirement may be customized in order to reduce requirements and save costs.

The software tool takes the equipment characteristics, entered by contract officers, program managers, engineers, or the acquisition team in general, and based on these inputs, will tailor the requirements, where feasible, while still minimizing EMI Risk. The concept of the software is similar to some commercial tax preparation packages where the user is taken step-by-step through several screens asking about all sources of income and deductions. In this case, the user will answer questions concerning the equipment parameters and characteristics, with the resulting output being the tailored test requirements and limits.

The first function of the EMC Software cost reduction tool will be to categorize shipboard equipments into groups, and then by categories of equipment. Groups such as HM&E, Supply and Support, Interior Communications, C4I, and Navigation, to name a few, will allow the tool to start to develop tailored EMC requirements. Systems to be installed both topside and below decks, if applicable, on a certain ship class will have tailored MIL-STD-464A EMV levels. The categories of equipments can even be subdivided based on the risk of impacting mission performance. Further, contractual verbiage can be developed based on the equipment characteristics and known EMC criteria selected. The tool will also have a database of COTS or other equipment that has been previously evaluated or meets certain commercial EMC criteria.

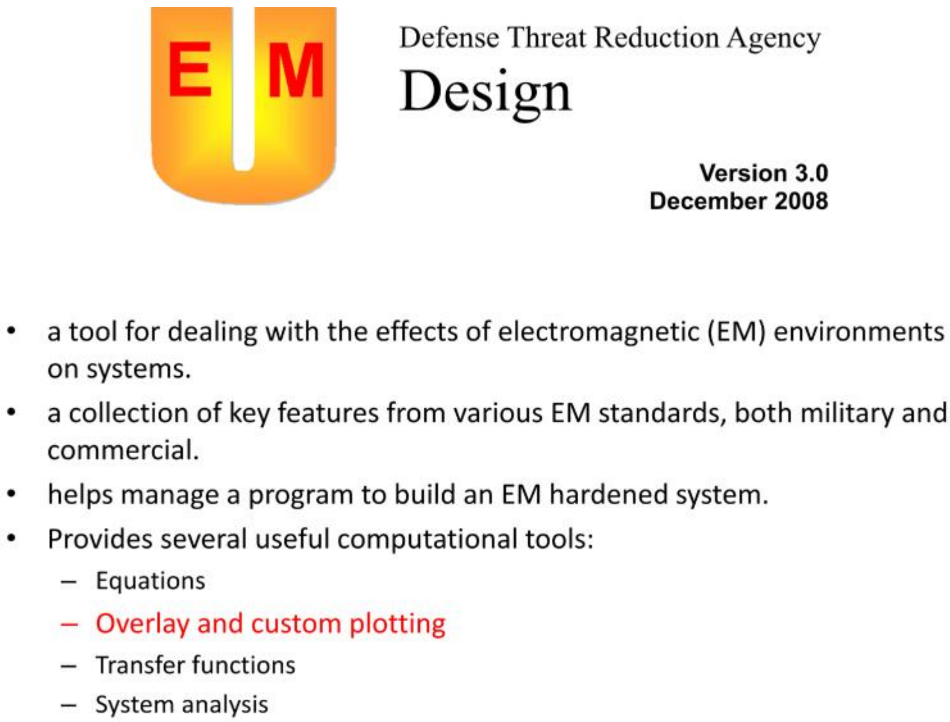
Many times an existing acquisition needs to be updated or upgraded. This software tool has an 'upgrade' acquisition function where the user can tailor EMC requirements for the upgraded parts to modify an existing piece of equipment or system. When an equipment such as COTS within a certain system becomes obsolescent in a few years, replacement of the equipment becomes necessary. Typically these equipments are housed in racks, with the rack having been previously EMI qualified. When this happens, some commercial EMC requirement may be all that is needed in order to keep E3 risks low. The software tool will list alternative commercial requirements, or the user may be able to incorporate them into the equipment characteristics via the user interface.

This tailoring tool has an acquisition tracking database to maintain the tailored requirements throughout its lifecycle, and to keep the E3 community on a single page with regards to testing requirement and meeting particular E3 testing.

Introduction to Tailoring

The Tailoring software also implements another important function, that of a bulletin board. If a shipyard E3 engineer should have a question in reference to tailoring, testing, or procedures, the bulletin board provides a localized place where NAVSEA staff can receive and respond to contractor E3 queries. This bulletin board function is expected to dramatically increase the ease of finding the correct contact, and dramatically decrease the response time.
The tool can be access at: https://www.em-tartt.us/.

B. UEM - Unified Electromagnetic Design

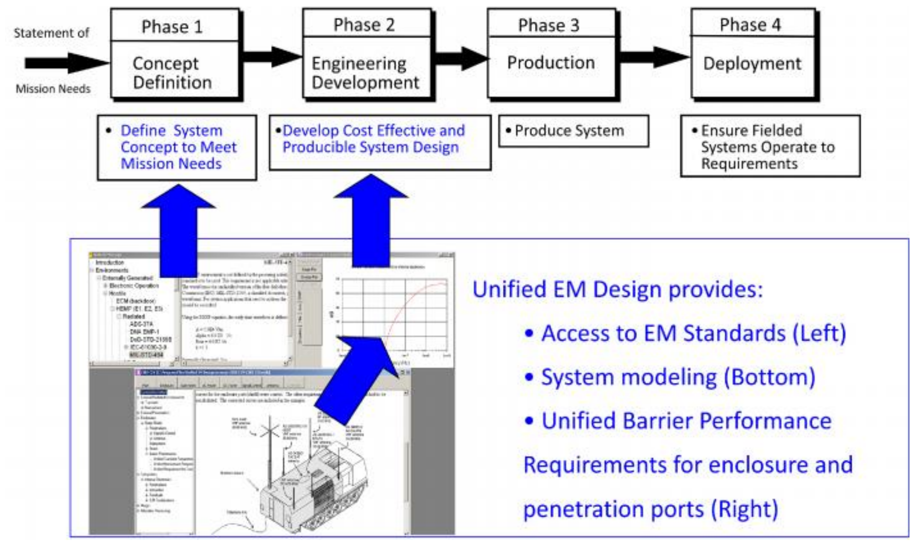


The Unified Electromagnetic (UEM) Design code is a tool for dealing with the effects of electromagnetic (EM) environments on systems. There are many diverse types of EM environments and effects, and they are all brought together in this code (hence, the term "Unified"). A major part of the code is a collection of key features from various EM standards, both military and commercial. In considering EM hardening of a system, the UEM Design code emphasizes an approach that protects against EM fields in general, not hardening individually for each separate effect (another reason for the term "Unified").

There are several aspects to this code. Partially it is like a textbook, discussing EM effects on systems, and how to protect against adverse EM effects. Some of the resulting computational models are interactive, in which the user can modify parameter values to tailor the results to the user's cases of interest. Part of the code also goes beyond this, allowing the EM design of the user's system to be inserted into the code for evaluation.

The UEM Design Code helps manage a program to build an EM hardened system. It provides guidance on what steps are needed in such a process. It's tools help select requirements that will allow the hardened system to be built. While it does have some computational ability, it does not provide detailed calculations of system responses in an EM environment.

Application of UEM



Summary

- Available free of charge to government agencies and their contractors
  - Request form at www.uemdesign.com
  - ITAR restrictions apply
- Version 3.0 released February 2009
  - Vista compatible
  - Search function
  - MIL-STD-461 Emissions
  - Draft MIL-STD-464B HPM environments - NOT Endorsed by DTRA
- Verification and Validation report included with release CD

1. Unified EM Design Software Request Form

MEMORANDUM FOR DTRA/NTSA (Mr. Michael Rooney)

Request you provide (Name of Recipient) ____ of (Organization) ____

(Phone) ____________________ (FAX) ________________ with a copy of the **Unified EM Design** software installation CD.

Please check below:

☐ This government agency is engaged in the development of E3 protection requirements for military systems. (State specific application) ______________________________

____.

☐ This contractor is required under contract ___________________________ to develop E3 protection requirements for military systems. (State specific application) _______________

____

Sponsoring Government Agency is (Name)____________________________________

(Government POC Name) _________________________ (Office) ________________

(Address) ____

(Phone) _________________ (FAX) _____________ (e-mail) _________________

Signature block of Government Sponsor:

____

(date) _________________

Mail the **Unified EM Design** software installation CD to:

____

____

____

(Send order form to: ATK, Attn: UEM Design Administrator, 8560 Cinderbed Road, Suite 700, Newington, VA 22122-8560. Fax: (703) 536 0284, e-mail: bob.gray@ieee.org.)